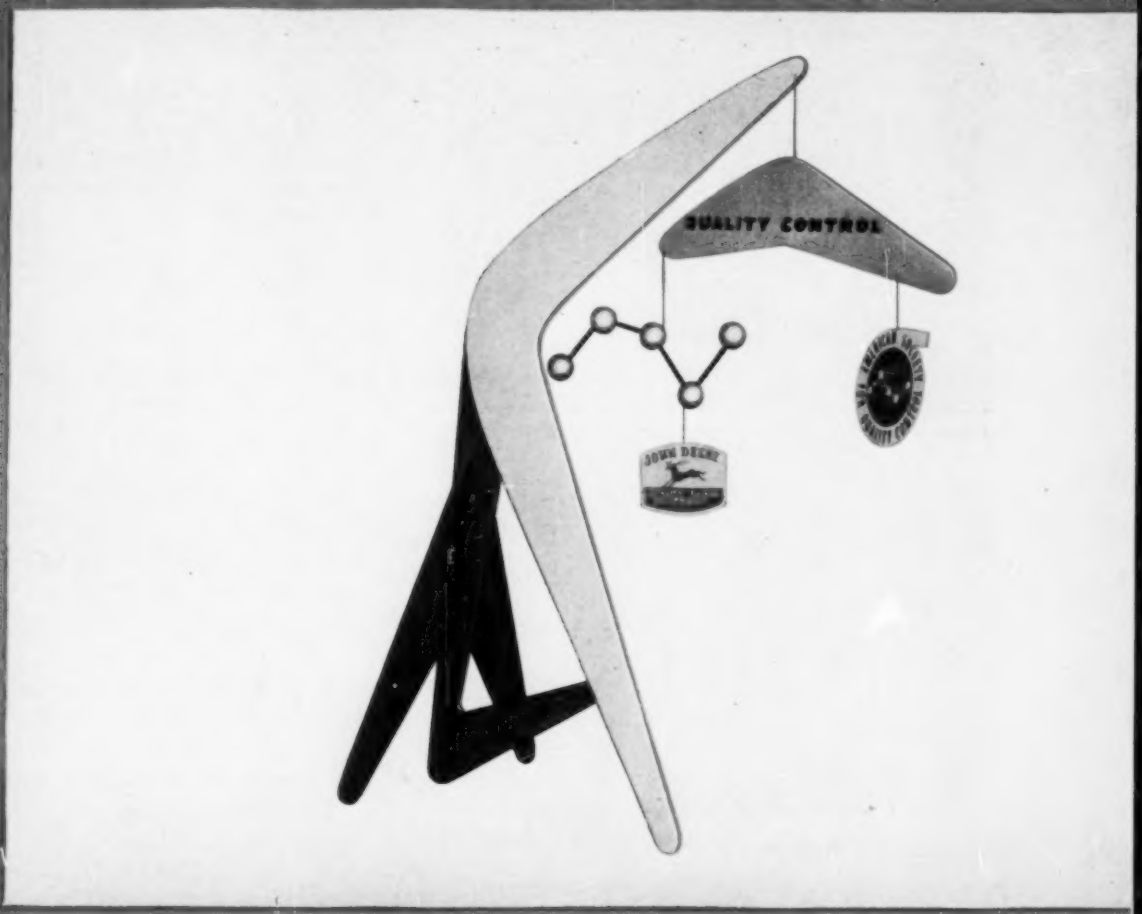
Industrial QUALITY CONTROL

MARCH, 1954 Vol. X No. 5



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Why the *Dial Type Precisionaire* IS THE BEST BUY In Dial Air Gaging

- The amplifying mechanism is capable of millions of cycles without appreciable wear or loss of adjustment.
- Lightning Quick, dead-stop pointer action—no fluctuation.
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- Because of scale design, there is no parallax—accurate readings from any angle.
- Quick spindle changeover.
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- It is completely adequate for tolerance ranges from .0001" to .003" with enough scale length above and below to evaluate undersize and oversize dimensions.
- It is small, compact and sturdy enough to withstand rough handling in the shop.

Gage Division, The Sheffield Corporation
Dayton 1, Ohio, U.S.A.

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6277

BOLTING VOICES TOGETHER

Adjusting casing over splice in polyethylene cable. Edges and ends are sealed with a new Butyl rubber compound that won't harden, dry out or lose adhesion even in extreme heat or cold.

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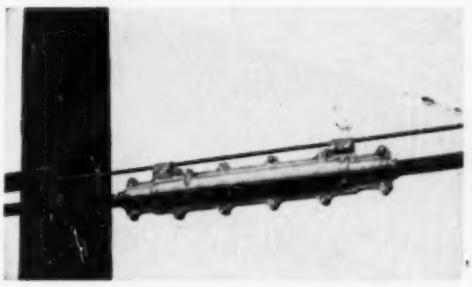
But at thousands of splices, the sheath must be thoroughly sealed against moisture. Laboratories engineers developed a protective casing which is quickly and simply bolted in place. The edges and ends of the casing are *permanently* sealed with a new compound developed by Laboratories rubber chemists.

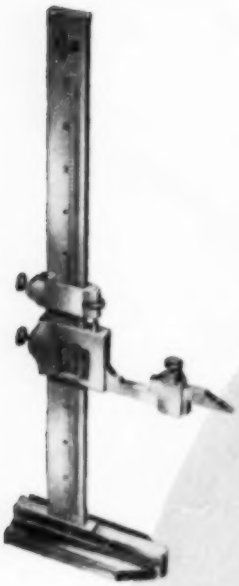
Now, economical polyethylene cable can be installed much faster and at lower cost. Here is another example of how Bell Laboratories continually finds ways to keep telephone service high in quality, while the cost stays low.



CLOSED CASING IN PLACE

BELL TELEPHONE LABORATORIES

EXPLORING AND INVENTING, DEVISING AND PERFECTING, FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE



Vernier Tools have machine-divided, evenly cut graduations, easily read to .001". Precision fitting slides permit smooth, precise adjustment.

Versatile Electronic Amplifier permits "plugging in" of various devices for countless gaging set-ups and measurements. Reads in .0001" to .00001".

Fastest Way to Positive Quality Control

You can make faster, more positive accuracy checks at any stage of production when you have the *complete* line of Brown & Sharpe Precision Tools. All the tools in this widely-diversified line are designed for maximum ease-of-use. At the machine, on the bench, or in your inspection departments, they assure you speed *plus* consistent accuracy on every job.

Illustrations show only a few Brown & Sharpe Precision Tools. For a description of the *complete* line and its many advantages, write for Catalog 35. Brown & Sharpe Mfg. Co., Providence 1, R. I., U. S. A.

B·S

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Permanent Magnet Base Dial Test Indicators with "on-off" control can be quickly, firmly fixed in any position . . . for the most difficult settings.

Johansson Gage Blocks. Made in 3 guaranteed accuracy standards . . . ± .000002", ± .000004", ± .000008" per inch. Many accessories extend usefulness.

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Intrimik Internal Tri-Point Micrometer measures bores and holes directly over a wide range . . . eliminates expensive plugs and setting rings.

Industrial Quality Control

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HARRY B. MARSH

With deepest regret, we report the death, at age 81, of Harry B. Marsh, a staunch friend and founding member of our Society. Although Mr. Marsh probably was best known for his work in the field of market research, it was his active interest which contributed in a large measure to the formation of the Indiana Society for Quality Control, the forerunner of the present Indianapolis Section, and later to the integration of various local quality control sections into a national society. He served for two years as president of the Indiana Society for Quality Control.

He was a Purdue University graduate of 1896; a member of Sigma Nu fraternity, the Scottish Rite and Shrine and the Hagerstown Rotary Club.

After many years in engineering and consulting work, he joined the Market Research Department of Perfect Circle Corporation in 1930. It was during his years with this company that he developed the interest in quality control which lead to his many valuable contributions to our Society.

ETT

OUR COVER

This month's cover picture comes to us through the courtesy of Fred J. Halton, Jr., Assistant to the President of Deere and Company, Chicago, Ill. The subject of this cover is the pylon supported mobile which was the central feature of the company's exhibit at the Eighth Midwest Conference held in Davenport, Iowa, last fall.

And before you glance away too quickly, take another look at the symbolism which is portrayed by this mobile.

The central theme, of course, is the entire field of quality control which is represented by the first pendant. Suspended from this on the left is an idealized control chart plotting from which in turn hangs the company insignia. Industrial statistics are kept in balance by information and the demands of industry on the one hand and by knowledge from the field of quality control on the other.

And suspended from the quality control pendant on the right is the insignia of ASQC. This, of course, signifies that knowledge in the field of quality control is kept in balance both by the Society and by industry.

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by the
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Milwaukee 3, Wis.

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Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $10.00; for Senior Members, $12.00; for Fellows, $16.00. In each grade, $3.00 of the annual dues are allocated as a subscription to INDUSTRIAL QUALITY CONTROL. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

Membership in the Society is personal and professional, and is not open to corporations, companies, or other organizations.

Contributions to the Society from corporations, companies, and others for the support of its activities are welcomed and appreciated.

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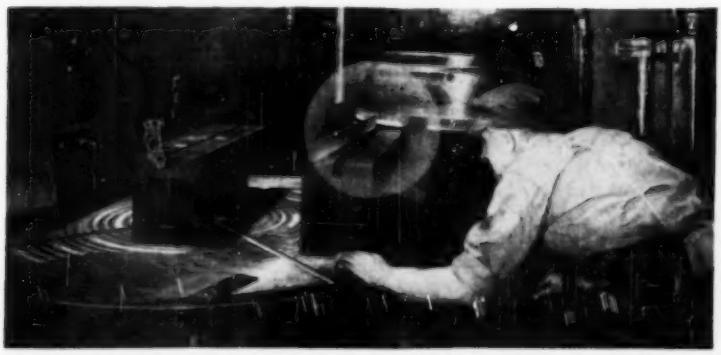
It pays to advertise in
INDUSTRIAL QUALITY CONTROL
Advertising space is available

"The new G Bond ALUNDUM® wheels give us double the production of former standard wheels." That's how a Massachusetts manufacturer sums up the performance of the new Norton wheels in grinding hardened high-speed steel textile blades. He adds: *"Wheels used on this job must be very free and cool cutting to avoid warping and burning the very thin stock."*



"I get a fast cut and good finish. They're the best and most versatile segments I ever used for this kind of work and I'm re-ordering ten sets," reports an Illinois customer using G Bond segments for surface grinding mild steel, cast iron and Meehanite — all three.

NORTON ABRASIVES

Making better products . . . to make other products better

These users say:

For surface grinding, the new G BOND beats them all!

Latest Norton wheels bring you the money-saving "TOUCH of GOLD"

Naturally, we've kept close watch on how the new G Bond wheels are doing. And we can report that throughout the range of precision and semi-precision grinding applications they're already away out in front. In the field of surface grinding, for instance, a composite statement by users of the new G Bond would run very much like this:

"G Bond wheels cut freer, cooler, faster — enabling us to take heavier cuts in costly high speed steels without drawing temper. They give us closer tolerances and smoother finishes. They dress easier and produce more pieces per dressing. Doing more work and a greater variety of work — per wheel, they outlast any wheels we ever used before."

G Bond Wheels for YOUR Surface Grinding

will bring new speed and economy to surface grinding jobs — thanks to their unique grain-holding structure that produces greatly improved cutting action. Remember, the G Bond is the most modern, most efficient vitrified bond ever developed — a typical Norton "Touch of Gold" achievement that steps up grinding performance and product quality while cutting grinding costs.

Ideal for Quality Control

If you are using quality control inspection methods you'll especially appreciate G bond wheels. Their ability to hold shape and require fewer dressings means more uniform performance. And because quality control is used in their manufacture you'll find them more uniform, too — from wheel to wheel and from lot to lot. Norton Company, Worcester 6, Mass. Warehouses in Five Cities — Distributors in All Principal Cities — see the yellow pages of your telephone directory.

W-1537

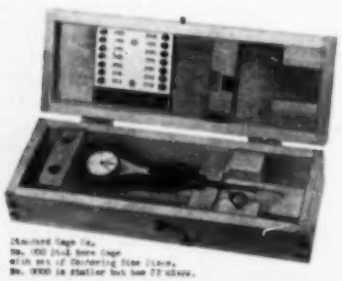
What's New?

ROY A. WYLIE, *Editor*

News releases describing new products and literature should be sent to:
George R. Foster, Mng. Ed.
Room 6123 Plankinton Bldg.
161 W. Wisconsin Ave.
Milwaukee 3, Wis

A new Profilometer Amplimeter has been announced by **Micrometrical Manufacturing Company,** 345 South Main Street, Ann Arbor, Mich. Designated Type QA Amplimeter, this unit was first demonstrated at the Metal Show in Cleveland in October. Although completely redesigned, it can be used with all Profilometer equipment, old or new. Features of the Type QA are: RMS or arithmetical average roughness readings can be selected by a switch; ready to use after only 30 sec. warm-up; no panel to open; conforms to proposed new ASA Standard B46.1 with regard to all technical details; high stability amplifier is not affected by normal temperature changes; is not sensitive to mechanical shock or vibration; meter has illuminated dial with two separate, color-coded scales; storage compartment in top of case; weighs 21 lb and is 8 in. wide x 15 in. front to back. For descriptive literature or a demonstration in your plant, contact Micrometrical Manufacturing Company.

* * *



Two new dial bore gages, covering the range from ⅛ to¼ in. have been announced by the **Standard Gage Company,** Poughkeepsie, N. Y. Size #0000 covers the range from ⅛ to 3/16 in. and size #000 covers the range from 3/16 to 1/4 in. Both sizes employ centering-size discs to centralize the head and at the same time serve as one of the contacts. Changing from one bore size to another is done by removing one disc and clamping on another. Both gages are offered as a "one-hole" gage to suit the user's specified dimension and tolerance, or as a general purpose gage for any dimension within the overall range. Range of the indicator is plus or minus 0.002 in., and zeroing of the instrument to the tolerance is accomplished by adjusting the capstan-type nut. The smaller gage will check to within 0.050 in. of the bottom of a blind hole, and the larger to within 0.062 in.

* * *

A new low-capacity torque wrench has been added to the line of standard torque wrenches manufactured by the **P. A. Sturtevant Company,** Addison, Ill. The new wrench, model F80-1-G has a capacity of 0 to 80 inch-grams and is calibrated in increments of 5 inch-grams. Other models of the same style are available in ranges from 0 to 8 inch-ounces and 0 to 16 inch-ounces.

* * *

A four-page brochure describing a centerless lapping machine and centerless lapping techniques is available from **Size Control Company,** 2500 West Washington Blvd., Chicago, 12, Ill. The brochure explains how the Size Control centerless lapping technique and equipment reduces production costs and gives more accurate results than conventional lapping methods.

* * *

Cosa Corporation, 405 Lexington Avenue, New York 17, N. Y., is importing a vertical, mechanical comparator manufactured by the Sigma Instrument Company, Letchworth, England. Completely mechanical, it may be set up anywhere in the plant without making an electrical connection. Magnifications of 500, 1000, 1500 and 3000 and capacities of 6 and 12 in. are available. All moving parts are mounted in patented ball bearings to reduce wear and assure repeated accuracy of readings. Vertical adjustments are made on both table and head, with final adjustment on the scale. Limit indicators may be locked in position. Eight models are available, each with reversible anvil, throat depth of 3¼ in. and an easily read 6-in. scale. Delivery is immediate from New York stock.

* * *

Three new gaging devices of interest to quality control people have recently been announced by **Federal Products Corporation,** 1144 Eddy

Street, Providence 1, R. I. The first is the Eccentricator Model A 70, which eliminates the need for observing maximum and minimum indicator readings and computing the difference when measuring workpieces for eccentricity. The unit can be used, in special applications, for checking run-out, squareness, straightness, wobble, etc., while ignoring normal variations in size of different workpieces. This instrument, used with suitable indicating power units either electric or electronic, is adjustable over a tolerance range of 0.0001 to 0.035 in. T.I.R. Multiple units may be mounted on 9/16 in. centerline, in manual, semi-automatic or automatic gaging devices.

Federal Products has also introduced a combined air and electric gage to check two diameters of a highly polished bearing simultaneously. A dual air snap gage is used to take the measurements, which are then transferred through an air-electric switch to an Electricator unit. This unit operates a set of tolerance lights—if both dimensions are good, the green light flashes; if either diameter is oversize, a red light flashes. The Dimensionair dials will tell the operator which dimension is off and how much. A high degree of accuracy combined with maximum inspection speed are claimed for this unit.

The third new product announced by Federal Products is an electric grinding gage to provide automatic control of cylindrical grinders. The gage combines an Arnold grinding gage frame and caliper with a Federal Electricator instead of the regular dial indicator, plus a power or control unit. With the electric grinding gage, the operator need not stop grinding to gage the work for size. Automatic control of the grinder begins as soon as the gage is snapped on the work, either before or during the grinding cycle. The gage rides the work during the grinding cycle and controls the wheelhead feeding mechanism, grinding rapidly until the work diameter nears finished size, then changing over to a slow spark-out feed. As final size is reached, the wheel is automatically retracted. Accuracy of 0.00005 in. over a prolonged period of time is claimed for this control gage.

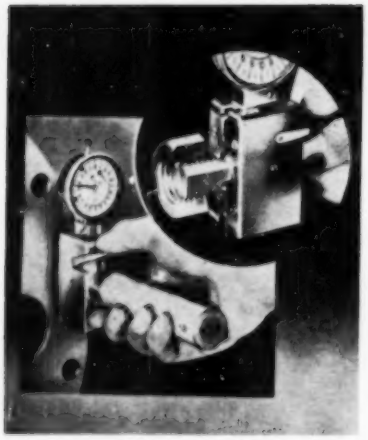
* * *

Non-destructive testing and sorting of accidentally mixed or incorrectly processed metal parts can be done speedily by the new Model C-1 Cyclograph, announced by the **J. W. Dice Company**, Englewood, N. J. Ferrous and non-ferrous metals can be sorted as raw stock, semi-finished and finished parts by their metallurgical characteristics such as analysis, hardness, structure, case depth, etc. With a known and acceptable part used as a standard in adjusting the instrument, unwanted parts are separated from the good ones manually by an operator, or, in conjunction with a Type 407 Automatic Relay Unit, by an automatic sorting device. The relay unit sends out a signal whenever an off-standard part passes through the test coil, and this signal can be used to operate a reject gate, marking device, or other reject means. Size and shape of the part is no problem, for coils can be wound for any size opening desired.

* * *

The **George Scherr Company**, 200 Lafayette Street, New York 12, N.Y., has announced a new line of indicating thread gages. One is a roller thread pitch diameter comparator gage and the other a dial thread plug gage for checking internal threads. All errors due to unequal pressure and "feel" are eliminated, allowing quick inspection by unskilled operators. The roller thread pitch diameter comparator gage has an indicator gage reading in 0.0001 in. and is set by means of a master thread gage. A zero setting thumbscrew and tolerance hands are provided. The thread to be checked is inserted between two rollers and variations in pitch diameter are quickly read from the dial. Special rolls are needed for every type of thread and lead. Range is up to 2 in. diameter.

The dial thread plug gage employs three interchangeable measuring jaws, one of which retracts between the other two. The jaws must first be inserted into a master ring gage and the indicator set to zero, then used on the work. Variations are quickly observed on the dial and tolerances are marked by two adjustable tolerance hands. The instrument comes in three sizes for ranges of thread diameters 3/16 to 1 in., 1 1/16 to 2 1/16 in. and 2⅛ to



4¾ in. A separate set of measuring jaws is necessary for every size and type of internal thread.

★ ★ ★

Brush Electronics Company, 3405 Perkins Avenue, Cleveland 14, Ohio, announces a new direct reading accessory for use with their Uniformity Analyzer, an instrument which measures and records on paper the variations in weight per unit length of yarn, roving and sliver. The new accessory, Model BL-814 Automatic Evaluator, is a portable device which indicates the same average peak-to-peak readings that would be obtained from chart calculations. There is direct correlation between data obtained from both chart and Automatic Evaluator, and defects in the material, which might be averaged out in area reading devices are shown in their proper perspective with the use of this unit. This accessory enables an operator to obtain complete non-uniformity data from a 1000 foot sample of yarn in 3½ min. and practically eliminates the need for chart calculations. The Automatic Evaluator was developed jointly by the Institute of Textile Technology, Charlottesville, Va., and the Brush Electronics Company, and is applicable to all new and modified Uniformity Analyzer units.

★ ★ ★

A new Gear Analyzer is being manufactured by **Optical Gaging Products, Inc.**, 26 Forbes Street, Rochester 11, N. Y. Used with a Model 3 Kodak Contour Projector, this analyzer will check involute profile, fillet interference (or clearance), outside diameter, root diameter, pitch diameter, backlash, tooth-to-tooth spacing, modified tooth form, tapered teeth, tooth crowning, first and last contact points, and off axis teeth. A wide range of gear sizes may be checked and no master gear is required. Direct observation of a magnified gear image allows inspection, analysis, and gaging of the gear under simulated operating conditions.

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Mount Vernon, New York

Publishers of Management Aids for Business and Industry Since 1911

WHAT'S THIS?

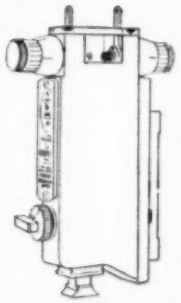
HIGH SPEED 100% INSPECTION

SIGMA

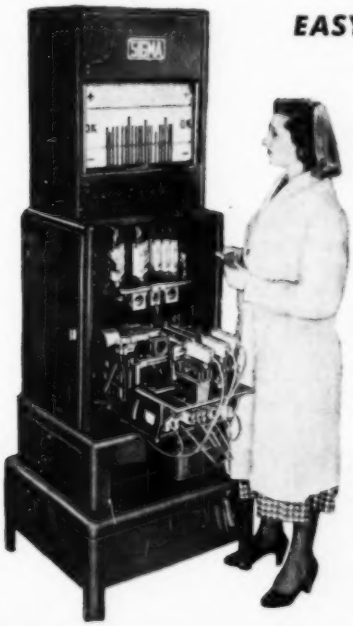
One machine is accurately checking 8 dimensions simultaneously—separating correct, oversize, and undersize parts at a rate of 2100 an hour.

Two girls now handle an inspection job that formerly took six—and human errors have been eliminated.

Eight, standard Sigma gauges, like this one: have been mounted together for rapid, accurate inspection of mass produced parts. Each gauge, accurate to within .00005", measures one dimension. More (up to 30) or fewer gauges could have been used, depending on the number of dimensions to be checked. These gauges, with standard Sigma mounting units, and special fixtures where necessary, can be set up to inspect parts a fraction of an inch long, or several inches long, a foot, or longer.

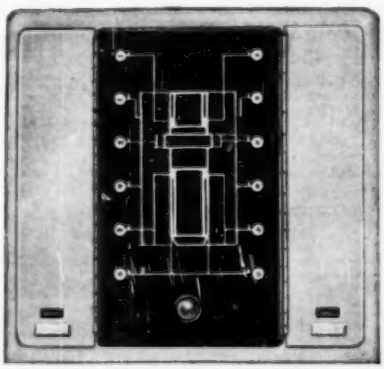


Depending on the arrangement, they can check internal and external diameters, length, depth, or other characteristics. The type of parts and the method of feeding determine inspection rates—hand feed: up to 600/hr.; semi-automatic: up to 900/hr.; fully automatic: up to 3500/hr. or more. Gauges are quickly and easily set to required tolerances and change-over from inspecting one type of part to another can be done within 10 or 20 minutes.



EASY-TO-READ INDICATORS WITH SIGMA EQUIPMENT

The semi-automatic Turbine and Compressor Blade Inspector (left) is an excellent example of Sigma's solution for a difficult inspection problem involving 18 dimensions. Fixtures are replaceable—each machine can inspect a wide range of different type parts. Gauges are connected to a Liquicolumn Indicator which has tubes of colored liquid set beside graduated scales—liquid levels indicate actual sizes of dimensions being checked. Magnifications can be varied easily by the user. Alternate indicator (right) uses electrical signals—green light for acceptable parts, red lights indicate dimensions below tolerances, yellow lights for those over. Built-in counters tabulate the number of parts submitted for inspection and the number accepted.



Contact us and get details on the Sigma equipment best suited to your high speed, multi-dimensional inspection problems.

COSA CORPORATION

405 Lexington Ave., New York 17

Your source for all Precision Machine Tools—from Small Bench Lathes to Large Boring Mills

IN DETROIT AREA contact DETROIT-COSA CORPORATION, 16923 James Couzens Highway, Detroit 35, Mich.

A Method for Handling Errors in Testing and Measuring

ALAN R. EAGLE

Broadview Research & Development, Burlingame, Calif.

INTRODUCTION

There are in the process of manufacture today a large variety of highly complex electronic and electromechanical equipments whose reliability (and, therefore, usefulness) is entirely dependent upon the reliability of the component parts and systems. In controlling the quality of this type of product, it is not only necessary to perform environmental and life tests on all components, but it is also imperative that component systems be tested against performance specifications with a very high degree of accuracy. This requires 100 percent testing, and it also requires that an allowance be made for inherent test errors resulting from lack of precision or repeatability in the test equipment and/or test personnel. The allowance for test errors takes the form of test specifications set inside the desired performance specifications by an amount sufficient to insure that no non-conforming units will be accepted as the result of a test error. The factors which should be considered in the setting of these test specifications are discussed in this article. A numerical example is included at the end of the paper to illustrate the method to be used in handling a practical situation. Mathematical considerations are largely deferred to the appendix.

ESTABLISHMENT OF TEST SPECIFICATIONS

The necessity for establishing test specifications inside of performance specifications where extreme accuracy is desired can be seen from the diagram in Fig. 1.

A unit whose true measurement occurs just above the upper performance specification could give a reading at any point on the scale between A and B, the extreme values of the test error. Therefore, in order to prevent the acceptance of any units which lie outside the performance specifications, it is necessary to set test specifications within the performance specifications and to accept units under production conditions on the basis of these test specifications. To determine just how far inside the performance specifications the test specifications must be set requires the consideration of the probability aspects of the situation. This can best be illustrated by the diagram in Fig. 2.

The probability of occurrence of an error at either extreme of the test error range is small, assuming that test errors have an approximately normal distribution. At the same time, the probability of producing a unit with a value outside either performance specification is also small, assuming a normal distribution of manufactured units which is well centered and has an acceptable spread. Therefore, the probability of an article being produced outside either performance specification and being measured at an extreme value of the test error range is particularly small. These probabilities have been worked out exactly for various sizes of test errors and with test specifications set inside performance specifications by varying amounts. The results are presented as a family of curves in Fig. 3.

The curves in Fig. 3 show that test specifications must be set successively further inside performance specifications in order to provide constant protection as test errors get successively larger. The lowest curve shows that if test specifications are set inside by an amount equal to one standard deviation of the test error distribution, then the probability of accepting a non-conforming unit due to a test error will be less than 0.5 percent, even if the standard deviation of the test errors is half as large as the performance specification. In entering the graph, the value of the performance specification to be used is the $\pm$ value of the allowable variation, i.e., one-half of the total allowable variation. For example, if the standard deviation of the test error is 3 v and if the performance specifications are 50 $\pm$ 10 v, enter the chart at the 0.3 point (3 $\div$ 10).

REJECTION OF CONFORMING UNITS

Since all units whose true values lie within the performance specifications are acceptable, but since only those units which give *readings* inside the *test* specification will be accepted, a portion of the acceptable units will be rejected. Naturally, the tighter the test specification in relation to the performance specification, the

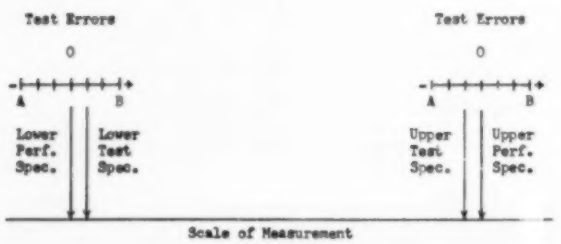


Figure 1

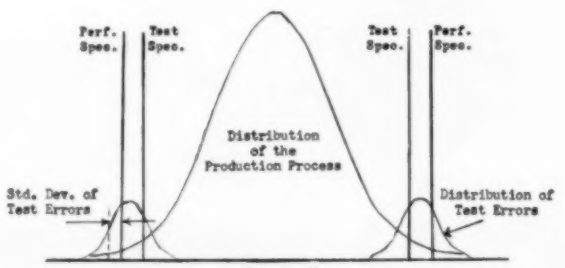


Figure 2

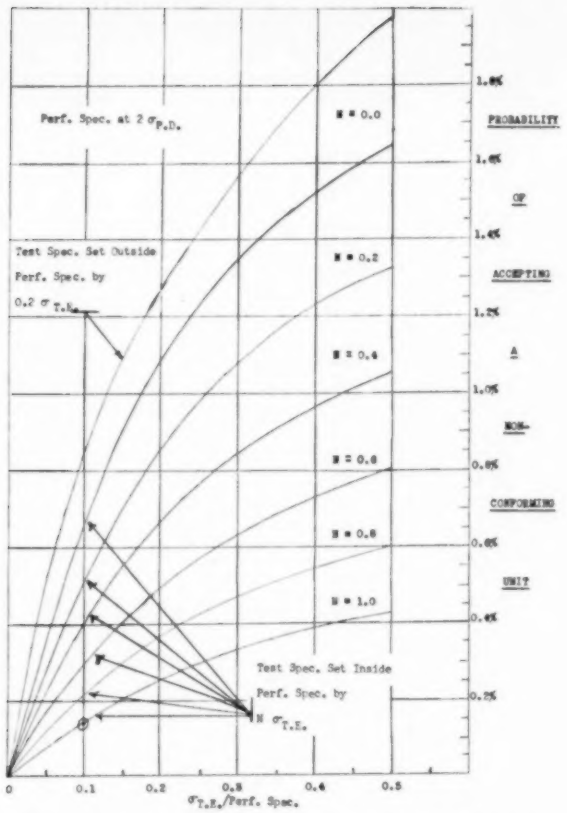


Figure 3—Probability of Accepting a Non-Conforming Unit

larger this proportion will be. Therefore, the larger the test error, the greater the proportion of acceptable units which are rejected. These relationships are shown in the curves of Fig. 4. The curves show how the proportion of acceptable units rejected increases as the size of the test error increases and as test specifications are set tighter. The cost of increased protection against units which do not conform is increased rejection of units which do conform.

Once the size of the test error has been determined experimentally (as explained below) the test specifications should be set according to Fig. 3, so as to keep the risk of accepting a non-conforming unit to a level determined by the functional requirement of the particular item tested. This risk must be held to a very low level when testing individual units which are assembled into a system whose reliability is the product of the reliability of the individual parts. Relatively larger risks can be tolerated when test measurements are made on a complete system, depending upon the functional importance of the system to the complete equipment.

Having established the tentative location of the test specifications, consult Fig. 4 to determine the percentage of conforming units which will be rejected. If this percentage is high, considering the time delay and cost associated with an erroneous rejection, adjust the setting of the test specifications to give an optimum balance between the probabilities of erroneous acceptance and erroneous rejection.

DERIVATION OF THE CURVES

The curves in Figs. 3 and 4 were computed by numerical integration of areas under the normal curve. This method of computation and the associated mathematical formulas are given in the Appendix. A word regarding the assumptions underlying the curves is in order at this point.

It is assumed that the distribution of the test errors is normal or approximately so with a mean error of zero. The distribution of the manufacturing process is also assumed normal with a spread such that the performance specification falls at two standard deviations of the production distribution. If the production distribution has a smaller spread than this, the probability of accepting a non-conforming unit and the percentage of conforming units rejected will both be smaller than shown on the curves, and the test error problem will be of minor importance. The opposite is true for a manufacturing distribution with a larger spread. Note that the curves as drawn apply to two-sided specifications. In dealing with one-sided specifications, the values for probability of erroneous acceptance and proportion of parts erroneously rejected should be divided by two.

DETERMINING $\sigma_{P.D.}$ AND $\sigma_{T.E.}$

Up to this point no mention has been made of the method of determining the standard deviation of the production distribution and the standard deviation of the test error. A means for determining these quantities experimentally was presented by Dr. Frank E. Grubbs in the *Journal of the American Statistical Association*,

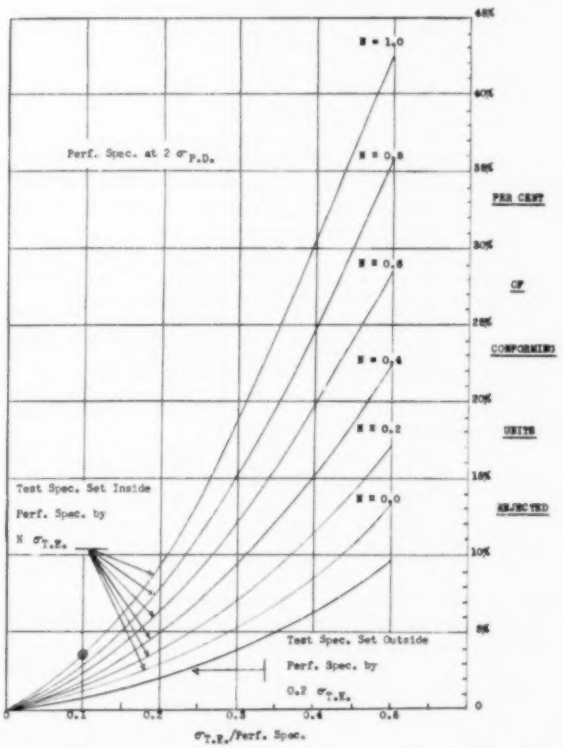


Figure 4—Probability of Rejecting an Acceptable Unit

June 1948, Vol. 43, 243-64. This method requires repeated measurements on a sample number of manufactured units on two or more different test set-ups. These test set-ups could be different pieces of test equipment, or the same piece of test equipment with different operators. The method of interpreting the data obtained in this manner and the relationship between the results and curves presented above can best be illustrated by a numerical example.

EXAMPLE

The data in Table I represent repeated measurements of 50 units taken on four different sets of test equipment. The performance specifications were set from functional considerations at 100 ± 9.000 units. The problem is to determine from these readings the standard deviation of the product distribution, the standard deviation of the test error of the four test sets A, B, C, D, and to set test specifications according to the values thus determined.

The first step in the solution is to calculate the variance of each column. Next, the sum of the cross products of each column with each other column is computed and these are used in the computation of covariance, according to the formula:

$$\text{Covariance A•B} = \frac{1}{n-1}\left[\sum_1^n X_A X_B - \frac{1}{n}\sum_1^n X_A \sum_1^n X_B\right]$$

The covariance of each column with each other column is computed and the six covariances thus obtained are averaged. This mean of the covariances is an unbiased estimate of the variance of the production distribution (formula 26 of the reference):

$$\sigma_{P.D.}^2 = 1/6(\text{Sum of the covariances})$$
$$= 1/6(105.1877)$$
$$= 17.5313$$
$$\sigma_{P.D.} = 4.19$$

The next step is to find the standard deviation of the test error of each test set. An estimate of this quantity is given by the following formula (formula 24 of the reference):

$$\sigma_{T.E._A}^2 = \sigma_{X_A}^2 - \frac{2}{N-1}\left[\begin{matrix}\text{Sum of the Covariances}\\ \text{involving test set A}\end{matrix}\right]$$
$$+ \frac{2}{(N-1)(N-2)}\left[\begin{matrix}\text{Sum of the Covariances in which}\\ \text{test set A is not involved}\end{matrix}\right]$$

where N is the number of test sets which in this case is four. Therefore

$$\sigma_{T.E._A}^2 = 21.93795 - \frac{2}{3}(53.350255) + \frac{1}{3}(51.827461)$$
$$= 3.64027$$
$$\sigma_{T.E._A} = 1.91$$

Similar calculations were performed to determine the standard deviation of the test error of test sets B, C and D with the following results:

$$\sigma_{T.E._A} = 1.91 \qquad \sigma_{T.E._C} = 2.32$$
$$\sigma_{T.E._B} = 1.97 \qquad \sigma_{T.E._D} = 1.42$$
$$\sigma_{P.D.} = 4.19$$

TABLE I—Repeated Measurements of 50 Units on Four Test Sets

Test Set A X_A	Test Set B X_B	Test Set C X_C	Test Set D X_D
92.46	94.01	93.72	95.16
106.42	99.50	102.42	103.23
98.47	99.78	98.61	98.34
102.31	103.07	98.07	101.39
104.36	107.11	107.53	105.75
105.72	104.18	106.43	103.05
101.63	98.68	101.49	98.40
95.05	97.43	97.47	97.80
92.36	88.62	91.14	91.09
106.33	105.14	100.02	105.60
93.65	90.97	97.07	92.71
108.21	107.65	106.12	106.61
99.41	99.15	94.40	97.10
99.43	96.66	96.71	96.08
97.68	95.57	96.16	98.09
104.92	108.30	103.75	103.12
100.18	98.22	98.33	101.28
101.77	99.35	104.87	97.27
101.35	106.50	102.27	102.38
95.29	94.35	92.50	91.98
98.53	93.88	98.07	96.84
105.72	106.00	101.55	106.99
94.96	90.79	91.68	93.99
104.07	106.06	103.86	103.83
106.77	108.42	108.65	104.43
103.90	100.59	100.12	100.73
100.33	99.43	96.69	103.59
105.54	105.26	107.45	107.90
104.20	102.71	102.34	103.85
98.47	99.39	101.40	97.43
90.85	96.70	96.95	96.81
104.58	106.50	106.28	106.88
96.73	99.31	98.77	98.40
94.14	96.66	100.48	99.19
99.66	101.16	96.11	97.86
111.24	107.32	109.37	109.08
108.55	107.91	105.64	108.78
104.64	104.93	104.37	106.32
101.05	98.74	102.08	101.81
97.67	104.20	97.83	99.04
100.54	100.30	101.01	99.26
96.74	99.85	98.84	99.88
103.16	100.13	104.65	100.97
96.93	103.42	102.58	99.05
97.01	94.92	94.48	95.43
94.68	97.81	100.88	93.76
100.76	98.37	101.09	99.65
98.87	100.02	102.27	100.45
104.48	102.79	101.05	102.18
101.60	100.12	102.62	101.74
$\Sigma X = 5035.37$	$\Sigma X = 5028.93$	$\Sigma X = 5027.23$	$\Sigma X = 5022.55$
$\bar{X} = 100.7074$	$\bar{X} = 100.5786$	$\bar{X} = 100.5446$	$\bar{X} = 100.4510$
$\sigma^2 = 21.93795$	$\sigma^2 = 23.701198$	$\sigma^2 = 19.631484$	$\sigma^2 = 19.75086734$

Cross Products

$\Sigma AB = 507,367.2389$	$\Sigma BC = 506,479.4749$
$\Sigma AC = 507,082.0184$	$\Sigma BD = 506,086.7563$
$\Sigma AD = 506,703.0745$	$\Sigma CD = 505,756.3977$

Covariances

A•B = 18.70967142	B•C = 17.30040204
A•C = 16.38277346	B•D = 18.89201836
A•D = 18.2678102	C•D = 15.63504081
53.36025508	51.82746121

Total Covariance = 105.18771629

The standard deviation of the production distribution is such that the performance specifications fall at (9.000/4.19) $\sigma_{P.D.} = 2.15\,\sigma_{P.D.}$ This is fairly close to the assumed conditions under which the curves in Figs. 3 and 4 were computed (performance specifications at 2 $\sigma_{P.D.}$). The largest test errors occurred on test set C, which had a standard deviation of test error of 2.32. This is taken as the maximum expected test error standard deviation for all four sets. The ratio of the standard deviation of the test error to the performance specifications is 2.32/9.000 = 0.26. This value is used to enter Fig. 3. It was felt that a degree of protection at 0.5 percent or better would be desirable. Figure 3 shows that this degree of protection would be assured by setting test specifications inside performance specifications by an amount equal to $0.8\sigma_{T.E.}$ However Fig. 4 shows that this setting would result in the rejection of approximately 13 percent of the conforming units submitted. Since

the costs and the time losses which would result from rejecting a conforming unit are large, this figure of 13 percent is too high. Hence, a compromise was reached by setting test specifications inside performance specifications by $0.4\sigma_{T.E.}$, assuring a protection of 0.8 percent (Fig. 3) and reducing the proportion of conforming units rejected to 8 percent (Fig. 4).

$$0.4(2.32) = 0.928$$

$$9.000 - 0.928 = 8.072$$

Test specifications are therefore set at 100 ± 8.072.

APPLICATIONS AND CONCLUSION

The comments and example above are intended to illustrate the fundamentals involved in the test error problem. Actual situations will seldom coincide exactly with the assumed conditions of the example. The method illustrated for determining the standard deviations of the production distribution and the test errors of different test set-ups is quite general and can be used in most situations. All that is required is a series of repeat measurements on 30 or more units taken on two or more different test set-ups. Manipulating this data through the given formulas provides the standard deviation figures required for evaluating the extent of the test errors in relation to the production distribution.

The curves given in Figs. 3 and 4 apply to a special situation, namely one in which the performance specifications lie at approximately $\pm$ 2 times the standard deviation of the production distribution. Also note that the curves for consumers risks (Fig. 3) all cover a range of very low percent risks. This is because these curves were drawn up for a product in which high reliability on the component parts was essential; and, therefore, consumers risks had to be restricted to a very low range. In many test and inspection situations, higher values of the consumers risk can be tolerated in order to achieve lower values of the producers risk. In order to make this approach generally applicable, the method for derivation of the curves is given in the appendix, and similar curves can be computed to correspond with actual situations encountered. A table of such curves drawn up to cover different situations encountered in practice would be a valuable contribution to the quality control field, and it is hoped that some interested person will take the initiative in preparing such a table.

Mathematical Appendix

The curves in Figs. 3 and 4 were computed through the use of an automatic calculator and a table of areas under the normal curve. Computational procedures are explained in this appendix and the mathematical formulas which apply are presented.

1. Computational Procedures for Fig. 3

The diagram of Fig. 5 demonstrates the calculation of the circled point on the bottom curve in Fig. 3. Assuming that the standard deviation of the test error is one tenth of the performance specification and that the performance specification is set at two times the standard deviation of the product distribution, then $1\sigma_{T.E.} = 0.2\sigma_{P.D.}$ The test specification is set inside the performance specification by $1\sigma_{T.E.}$ which amounts to $0.2\sigma_{P.D.}$ Therefore, the test specification cuts the production distribution at $1.8\sigma_{P.D.}$ $(2.0 - 0.2 = 1.8)$.

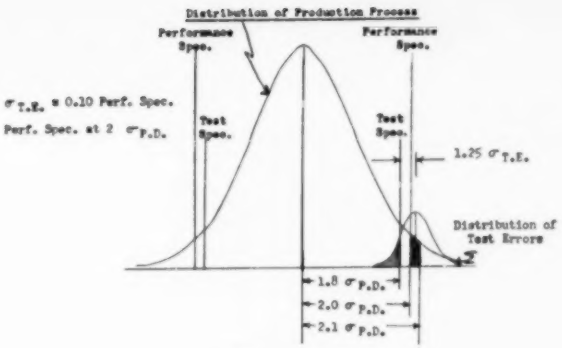


Figure 5

All units outside the performance specifications are non-conforming and should be rejected. We are interested in the probability that any of these units will be accepted. Consider the area of the production distribution which lies between 2.0 and 2.1 standard deviations on one tail of the distribution. This is the cross-hatched area shown in Fig. 5 and its magnitude can be read from a table of areas under the normal curve. This value is 0.0048, representing the probability of a particular unit being produced between 2.0 and 2.1 standard deviations of the production process.

The small normal curve in Fig. 5 represents the distribution of the test errors. With this distribution centered in the middle of the cross-hatched section (at $2.05\sigma_{P.D.}$) the test specifications will lie at $1.25\sigma_{T.E.}$ Only those units which read within the test specification will be accepted. Therefore the shaded area under the test error curve represents the probability that a unit whose true value lies in the cross-hatched section will be accepted. This figure can be read from a table of areas under the normal curve as the portion of the curve beyond 1.25 standard deviations. Its value is 0.1057.

Now with the probability of occurrence being 0.0048 and the probability of acceptance being 0.1057, the probability of occurrence *and* acceptance of a unit in the $2.0 - 2.1\sigma$ region is the product of these two probabilities or 0.000507. To obtain the total probability of acceptance, it is necessary to sum all such products over successive increments of area to the tip of the production distribution. These computations are shown in Table II from which it is seen that the sum in this case is 0.000715. Since the same probability applies for both the upper and lower performance specifications, this figure must be

TABLE II—Sample Calculations for Circled Point in Fig. 3

Prod. Dist. Interval in terms of $\sigma_{P.D.}$	Probability of Unit Occurring	Units of $\sigma_{T.E.}$ for finding Col. (4)	Probability of Unit Being Accepted	Probability of Occurrence and Acceptance
(1)	(2)	(3)	(4)	(2) x (4)
2.0 - 2.1	0.0048	1.25	0.1057	0.000507
2.1 - 2.2	0.0040	1.75	0.0401	0.000160
2.2 - 2.3	0.0032	2.25	0.0122	0.000039
2.3 - 2.4	0.0025	2.75	0.0030	0.000008
2.4 - 2.5	0.0025	3.25	0.00058	0.000001
2.5 - 2.6	0.0015	3.75	0.00017	0.000000
				0.000716

Total probability of accepting non-conforming units = 0.00143 = 0.14%

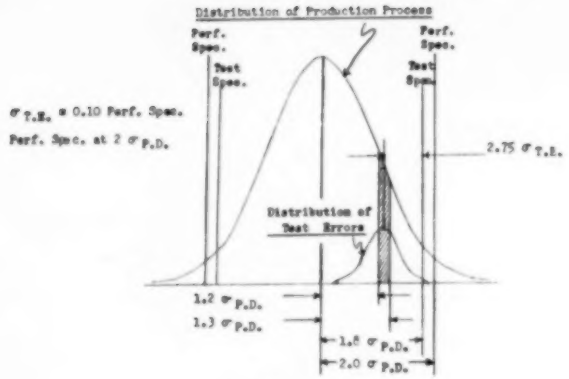


Figure 6

doubled to give the total probability of accepting a non-conforming part. The final value thus obtained is 0.0014 or 0.14 percent.

A similar set of calculations was carried out for each of the points from which this curve and all the other curves in Fig. 3 were plotted.

2. Computational Procedures for Fig. 4

The diagram in Fig. 6 demonstrates the calculation of the circled point in the top curve in Fig. 4. In this case we are interested in determining what percentage of acceptable units will be rejected because of test error. Using the same two assumptions of the previous section plus the additional assumption that three standard deviations of the test error will be the maximum error that can be made in either the plus or minus direction, then $1\sigma_{T.E.} = 0.2\sigma_{P.D.}$ and $3\sigma_{T.E.} = 0.6\sigma_{P.D.}$ For this curve the test specifications are set inside performance specifications by $1\sigma_{T.E.}$ and, therefore, cut the production distribution at $1.8\sigma_{P.D.}$ Since $0.6\sigma_{P.D.}$ corresponds to the maximum test error in either the plus or minus direction, no unit which occurs closer to the center of the production distribution than $1.2\sigma_{P.D.}$ will be rejected. A portion of the acceptable articles which lie between 1.2 and $2.0\sigma_{P.D.}$ will be rejected, and this is the percentage which we wish to determine.

Consider the portion of the production distribution in the $1.2 - 1.3\sigma$ region (shaded area in Fig. 6). A table of areas under the normal curve shows that 1.83 percent of the units will fall in this region. With the test error distribution centered at $1.25\sigma_{T.E.}$, the test specification will intercept the test error distribution curve at $2.75\sigma_{T.E.}$ The probability of rejection of a unit whose true measurement lies between 1.2 and $1.3\sigma_{P.D.}$ is represented by the area of the test error distribution beyond $2.75\sigma_{T.E.}$, which value is read from the tables as 0.3 percent.

TABLE III—Sample Calculations for Circled Point in Fig. 4

Prod. Dist. Interval in terms of $\sigma_{P.D.}$	Probability of Unit Occurring	Units of $\sigma_{T.E.}$ for finding Col. (4)	Probability of Unit Being Rejected	Probability of Occurrence and Rejection
(1)	(2)	(3)	(4)	(2) x (4)
1.2 – 1.3	0.0183	2.75	0.0030	0.000055
1.3 – 1.4	0.016	2.25	0.0122	0.000195
1.4 – 1.5	0.014	1.75	0.0401	0.000561
1.5 – 1.6	0.012	1.25	0.1057	0.001268
1.6 – 1.7	0.0102	0.75	3.2266	0.002311
1.7 – 1.8	0.0087	0.25	0.4013	0.003491
1.8 – 1.9	0.0072	−0.25	0.5987	0.004311
1.9 – 2.0	0.0060	−0.75	0.7734	0.004640
				0.016832

Total probability of rejecting acceptable units = 0.0336 = 3.36%

As in the previous section, the probability of producing units in this region which will be rejected is the product of 1.83 and 0.3 percent, and the total probability of rejection of acceptable units is obtained by summing all such products for each increment of area from 1.2 to $2.0\sigma_{P.D.}$ This figure is 1.68 percent as shown in the computations in Table III. Again, since an equal percentage of acceptable items will be rejected at the lower end of the production distribution, this figure must be doubled to give the total probability of rejecting units that are acceptable, which in this case is 3.36 percent.

A similar set of calculations was made for all points from which each curve of Fig. 4 was plotted.

3. Formulas

For the more sophisticated mathematician and for general applications, the required formulas are presented in this section.

Let

σ_x = the true standard deviation of the production distribution

σ_e = the standard deviation of the errors of measurement (The mean error is assumed equal to zero.)

$\pm k\sigma_x$ = the performance limits (The process average is assumed to be centered midway between the performance limits. In Figs. 3 and 4, k is assumed equal to two.)

b = the number of standard deviations of test errors at which the *test* specification limits are placed within the performance limits

Then it can be shown that the probability of accepting a non-conforming unit (Fig. 3) is given by

$$\frac{1}{\pi}\int_{k}^{\infty}\int_{-\frac{\sigma_x}{\sigma_e}(k+t)+b}^{\frac{\sigma_x}{\sigma_e}(k-t)-b} \varepsilon^{-(s^2+t^2)/2}\,ds\,dt \qquad (1)$$

or

$$2M\left[k, -\frac{k\sigma_x - b\sigma_e}{\sqrt{\sigma_x^2+\sigma_e^2}}, \frac{\sigma_x}{\sqrt{\sigma_x^2+\sigma_e^2}}\right]$$

$$-M\left[k, \frac{k\sigma_x - b\sigma_e}{\sqrt{\sigma_x^2+\sigma_e^2}}, \frac{\sigma_x}{\sqrt{\sigma_x^2+\sigma_e^2}}\right]$$

The function

$$M(h,k,\rho) = \frac{1}{2\pi\sqrt{1-\rho^2}}\int_{h}^{\infty}\int_{k}^{\infty} \varepsilon^{-\frac{x^2-2\rho xy+y^2}{2(1-\rho^2)}}\,dx\,dy$$

is given in Karl Pearson's, *Tables for Statisticians and Biometricians, Part II*, 1931, pp. 78-137. For negative h and k the following formulas hold:

$$M(h,k,\rho) = \frac{1}{2} - q(h) - M(h,-k,-\rho)$$

$$= \frac{1}{2} - q(k) - M(-h,k,-\rho)$$

$$= M(-h,-k,\rho) + q(-h) + q(-k)$$

where

$$q(t) = \frac{1}{\sqrt{2\pi}} \int_0^t \varepsilon^{-x^2/2}\, dx$$

Also the probability that a conforming unit will be rejected (Fig. 4) is given by

$$\frac{1}{\sqrt{2\pi}} \int_{-k}^{k} \varepsilon^{-s^2/2}\, ds$$

$$- \frac{1}{\sqrt{2\pi}} \int_{-k}^{k} \int_{-\frac{\sigma_x}{\sigma_e}(k+t)+b}^{\frac{\sigma_x}{\sigma_e}(k-t)-b} \varepsilon^{-(s^2+t^2)/2}\, ds\, dt \quad (2)$$

or

$$\frac{1}{\sqrt{2\pi}} \int_{-k}^{k} \varepsilon^{-s^2/2}\, ds$$

$$- M\left[-k, -\frac{k\sigma_x - b\sigma_e}{\sqrt{\sigma_x^2 + \sigma_e^2}}, \frac{\sigma_x}{\sqrt{\sigma_x^2 + \sigma_e^2}}\right]$$

$$- M\left[k, \frac{k\sigma_x - b\sigma_e}{\sqrt{\sigma_x^2 + \sigma_e^2}}, \frac{\sigma_x}{\sqrt{\sigma_x^2 + \sigma_e^2}}\right]$$

$$+ M\left[-k, \frac{k\sigma_x - b\sigma_e}{\sqrt{\sigma_x^2 + \sigma_e^2}}, \frac{\sigma_x}{\sqrt{\sigma_x^2 + \sigma_e^2}}\right]$$

$$+ M\left[k, -\frac{k\sigma_x - b\sigma_e}{\sqrt{\sigma_x^2 + \sigma_e^2}}, \frac{\sigma_x}{\sqrt{\sigma_x^2 + \sigma_e^2}}\right]$$

Now if we consider the special case discussed in this article, namely k = 2, take b = —0.2, 0, 0.2, 0.4, 0.6, 0.8, 1.0 (the curves of Figs. 3 and 4), and select values for $\sigma_e/2\sigma_x$ (the abscissa of the graphs), then it is easy to check points on these curves. This has been done for several points which were found to agree very accurately with the results of the computational procedure described in sections 1 and 2 of this appendix. The author acknowledges with appreciation the above formulas which were furnished by the referee.

On Setting Test Limits Relative to Specification Limits

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INTRODUCTION

The preceding article, "A Method for Handling Errors in Testing and Measuring" by Allan R. Eagle, brings up some very interesting and practical points, since in the past it has been common practice to set specification limits for various products on the basis of what can be tolerated in service use without taking into consideration the fact that errors of measurement will be made in testing the product for acceptability. Indeed, the setting of "test" specification limits* has been neglected, although it may be said that generally test limits and specification limits have coincided. Whereas, it is generally recognized that errors of measurement may be made or are made in connection with the testing of a product for acceptability, it appears that very little scientific progress has been made concerning the problem of just *where* test specification limits should be placed relative to the specified or intended limits when errors of measurement in testing are made. Under the assumption that the specification limits themselves are properly arrived at, it will be the purpose of this paper to study the most appropriate position of test limits.

AN EXAMPLE

Suppose it has been determined that a certain type of high voltage capacitor (cost, $4.00 each) will operate satisfactorily if the true capacity is not outside the range 0.100 ± 0.009 μf (the specification limits). Thus, in a 100 percent "screening" inspection those condensers for which the *true* capacity does not fall outside the interval 0.091 – 0.109 μf should be "accepted" for a certain use and the capacitors with true measurement below 0.091 μf or above 0.109 μf should be "rejected" or set aside for other uses.

It is easy to estimate the percentage or proportion of units which should be accepted or rejected if we know accurately the process level and the unit-to-unit standard deviation of the process or the product variability. Suppose, for example, that the process average is exactly at 0.100 μf and the true product variability (assuming no errors of measurement) amounts to a standard deviation of 0.0045 μf. Thus, assuming further that we have a normal distribution in capacity for the product units, we

*In this article the term "specification limits" is used to designate those limits within which the true value of the product should lie for it to be acceptable and useful. The term "test specification limits" or simply "test limits" will be used to mean those limits which should be applied to judge the acceptability of the product based on a set of measured values.

TABLE I

Specification Limits = $\mu \pm k\sigma_x$ Test Limits = $\mu \pm (k\sigma_x - b\sigma_\epsilon)$
A = Risk of accepting nonconforming unit (Consumer's Risk)
B = Risk of rejecting a conforming unit (Producer's Risk)
$b = -k(\sqrt{r^2+1} - r)$ = that value of b which will make A = B
$r = \sigma_x/\sigma_\epsilon$

r \ k	1.5	2.0	2.5	3.0	3.5	4.0
.50	b= -.9270 A= .1005 B= .1005 A+B=.2010	b= -1.2361 A= .0386 B= .0386 A+B=.0772	b= -1.5451 A= .0114 B= .0114 A+B=.0228	b= -1.8541 A= .0026 B= .0026 A+B=.0052	b= -2.1631 A= .0005 B= .0005 A+B=.0009	b= -2.4721 A= .0001 B= .0001 A+B=.0001
.75	b= -.7500 A= .0879 B= .0879 A+B=.1758	b= -1.0000 A= .0345 B= .0345 A+B=.069	b= -1.2500 A= .0104 B= .0104 A+B=.0208	b= -1.5000 A= .0024 B= .0024 A+B=.0048	b= -1.7500 A= .0004 B= .0004 A+B=.0009	b= -2.0000 A= .0001 B= .0001 A+B=.0001
1.00	b= -.6213 A= .0764 B= .0764 A+B=.1528	b= -.8284 A= .0305 B= .0305 A+B=.0610	b= -1.0355 A= .0094 B= .0094 A+B=.0188	b= -1.2426 A= .0023 B= .0023 A+B=.0047	b= -1.4497 A= .0004 B= .0004 A+B=.0008	b= -1.6568 A= .0001 B= .0001 A+B=.0001
2.00	b= -.3541 A= .0469 B= .0469 A+B=.0938	b= -.4721 A= .0193 B= .0193 A+B=.0386	b= -.5902 A= .0061 B= .0061 A+B=.0122	b= -.7082 A= .0015 B= .0015 A+B=.0030	b= -.8262 A= .0003 B= .0003 A+B=.0006	b= -.9443 A= .0000 B= .0000 A+B=.0000
3.00	b= -.2434 A= .0329 B= .0329 A+B=.0658	b= -.3246 A= .0136 B= .0136 A+B=.0272	b= -.4057 A= .0044 B= .0044 A+B=.0088	b= -.4868 A= .0011 B= .0011 A+B=.0022	b= -.5680 A= .0002 B= .0002 A+B=.0004	b= -.6491 A= .0000 B= .0000 A+B=.0000
4.00	b= -.1847 A= .0251 B= .0251 A+B=.0502	b= -.2462 A= .0104 B= .0104 A+B=.0208	b= -.3078 A= .0034 B= .0034 A+B=.0068	b= -.3693 A= .0008 B= .0008 A+B=.0017	b= -.4309 A= .0002 B= .0002 A+B=.0003	b= -.4924 A= .0000 B= .0000 A+B=.0000
5.00	b= -.1485 A= .0202 B= .0202 A+B=.0404	b= -.1980 A= .0084 B= .0084 A+B=.0168	b= -.2476 A= .0027 B= .0027 A+B=.0054	b= -.2971 A= .0007 B= .0007 A+B=.0014	b= -.3466 A= .0001 B= .0001 A+B=.0003	b= -.3961 A= .0000 B= .0000 A+B=.0000
6.00	b= -.1241 A= .0168 B= .0168 A+B=.0336	b= -.1655 A= .0071 B= .0071 A+B=.0142	b= -.2069 A= .0023 B= .0023 A+B=.0046	b= -.2483 A= .0006 B= .0006 A+B=.0012	b= -.2897 A= .0001 B= .0001 A+B=.0002	b= -.3310 A= .0000 B= .0000 A+B=.0000
7.00	b= -.1066 A= .0146 B= .0146 A+B=.0292	b= -.1421 A= .0061 B= .0061 A+B=.0122	b= -.1777 A= .0020 B= .0020 A+B=.0039	b= -.2132 A= .0005 B= .0005 A+B=.0010	b= -.2487 A= .0001 B= .0001 A+B=.0002	b= -.2843 A= .0000 B= .0000 A+B=.0000
8.00	b= -.0934 A= .0128 B= .0128 A+B=.0252	b= -.1245 A= .0053 B= .0053 A+B=.0106	b= -.1556 A= .0017 B= .0017 A+B=.0035	b= -.1868 A= .0004 B= .0004 A+B=.0009	b= -.2179 A= .0001 B= .0001 A+B=.0002	b= -.2490 A= .0000 B= .0000 A+B=.0000
9.00	b= -.0831 A= .0114 B= .0114 A+B=.0227	b= -.1108 A= .0048 B= .0048 A+B=.0096	b= -.1385 A= .0015 B= .0015 A+B=.0031	b= -.1662 A= .0004 B= .0004 A+B=.0008	b= -.1939 A= .0001 B= .0001 A+B=.0002	b= -.2216 A= .0000 B= .0000 A+B=.0000
10.00	b= -.0748 A= .0102 B= .0102 A+B=.0204	b= -.0998 A= .0043 B= .0043 A+B=.0086	b= -.1247 A= .0014 B= .0014 A+B=.0028	b= -.1496 A= .0003 B= .0003 A+B=.0007	b= -.1746 A= .0001 B= .0001 A+B=.0001	b= -.1995 A= .0000 B= .0000 A+B=.0000

TABLE II

Specification Limits = $\mu \pm k\sigma_x$ Test Limits = $\mu \pm (k\sigma_x - b\sigma_\epsilon)$
A = Risk of accepting nonconforming unit (Consumer's Risk)
B = Risk of rejecting a conforming unit (Producer's Risk)
$b \cong k/r$ = that value of b which will minimize (A+B)
$r = \sigma_x/\sigma_\epsilon$

r \ k	1.5	2.0	2.5	3.0	3.5	4.0
.50	b= -3.0000 A= .1332 B= .0004 A+B=.1336	b= -4.0000 A= .0455 B= .0000 A+B=.0455	b= -5.0000 A= .0124 B= .0000 A+B=.0124	b= -6.0000 A= .0027 B= .0000 A+B=.0027	b= -7.0000 A= .0005 B= .0000 A+B=.0007	b= -8.0000 A= .0001 B= .0000 A+B=.0001
.75	b= -2.0000 A= .1263 B= .0051 A+B=.1314	b= -2.6667 A= .0450 B= .0004 A+B=.0454	b= -3.3333 A= .0124 B= .0000 A+B=.0124	b= -4.0000 A= .0027 B= .0000 A+B=.0027	b= -4.6667 A= .0005 B= .0000 A+B=.0005	b= -5.3333 A= .0001 B= .0000 A+B=.0001
1.00	b= -1.5000 A= .1122 B= .0125 A+B=.1247	b= -2.0000 A= .0428 B= .0018 A+B=.0444	b= -2.5000 A= .0122 B= .0002 A+B=.0124	b= -3.0000 A= .0027 B= .0000 A+B=.0027	b= -3.5000 A= .0005 B= .0000 A+B=.0005	b= -4.0000 A= .0001 B= .0000 A+B=.0001
2.00	b= -.7500 A= .0640 B= .0239 A+B=.0879	b= -1.0000 A= .0273 B= .0074 A+B=.0347	b= -1.2500 A= .0088 B= .0016 A+B=.0104	b= -1.5000 A= .0022 B= .0003 A+B=.0025	b= -1.7500 A= .0004 B= .0000 A+B=.0004	b= -2.0000 A= .0000 B= .0000 A+B=.0000
3.00	b= -.5000 A= .0418 B= .0221 A+B=.0639	b= -.6667 A= .0182 B= .0077 A+B=.0259	b= -.8333 A= .0060 B= .0020 A+B=.0080	b= -1.0000 A= .0015 B= .0004 A+B=.0019	b= -1.1667 A= .0003 B= .0000 A+B=.0003	b= -1.2323 A= .0000 B= .0000 A+B=.0000
4.00	b= -.3750 A= .0304 B= .0189 A+B=.0493	b= -.5000 A= .0132 B= .0069 A+B=.0201	b= -.6250 A= .0044 B= .0020 A+B=.0064	b= -.7500 A= .0011 B= .0004 A+B=.0015	b= -.8750 A= .0002 B= .0000 A+B=.0002	b= -1.0000 A= .0000 B= .0000 A+B=.0000
5.00	b= -.3000 A= .0237 B= .0161 A+B=.0398	b= -.4000 A= .0103 B= .0062 A+B=.0165	b= -.5000 A= .0034 B= .0018 A+B=.0052	b= -.6000 A= .0009 B= .0004 A+B=.0013	b= -.7000 A= .0002 B= .0001 A+B=.0003	b= -.8000 A= .0000 B= .0000 A+B=.0000
6.00	b= -.2500 A= .0192 B= .0138 A+B=.0330	b= -.3333 A= .0084 B= .0055 A+B=.0139	b= -.4167 A= .0028 B= .0017 A+B=.0045	b= -.5000 A= .0007 B= .0004 A+B=.0011	b= -.5833 A= .0001 B= .0000 A+B=.0001	b= -.6667 A= .0000 B= .0000 A+B=.0000
7.00	b= -.2143 A= .0165 B= .0127 A+B=.0292	b= -.2857 A= .0071 B= .0050 A+B=.0121	b= -.3571 A= .0024 B= .0016 A+B=.0040	b= -.4286 A= .0006 B= .0004 A+B=.0010	b= -.5000 A= .0001 B= .0000 A+B=.0001	b= -.5714 A= .0000 B= .0000 A+B=.0000
8.00	b= -.1875 A= .0142 B= .0111 A+B=.0253	b= -.2500 A= .0061 B= .0044 A+B=.0106	b= -.3125 A= .0020 B= .0014 A+B=.0034	b= -.3750 A= .0005 B= .0003 A+B=.0008	b= -.4375 A= .0001 B= .0000 A+B=.0001	b= -.5000 A= .0000 B= .0000 A+B=.0000
9.00	b= -.1667 A= .0125 B= .0102 A+B=.0227	b= -.2222 A= .0054 B= .0041 A+B=.0095	b= -.2773 A= .0018 B= .0013 A+B=.0031	b= -.3333 A= .0005 B= .0003 A+B=.0008	b= -.3889 A= .0001 B= .0000 A+B=.0001	b= -.4444 A= .0000 B= .0000 A+B=.0000
10.00	b= -.1500 A= .0101 B= .0083 A+B=.0184	b= -.2000 A= .0048 B= .0037 A+B=.0085	b= -.2500 A= .0016 B= .0012 A+B=.0028	b= -.3000 A= .0004 B= .0003 A+B=.0007	b= -.3500 A= .0001 B= .0000 A+B=.0001	b= -.4000 A= .0000 B= .0000 A+B=.0000

find that the percentage outside the specification limits can be determined by taking the ratio 0.009/0.0045 = 2.00 and referring this to a table of the normal distribution. We find that 2.25 percent of the product will lie below 0.091 μf and 2.25 percent of the product will lie above 0.109 μf, so that 95.5 percent of the submitted capacitors—those not outside the 0.091 – 0.109 μf range—should be accepted and the remaining 4.5 percent of the units should be rejected. We emphasize in this connection that these represent the true proportions of product which should be passed or rejected in a screening inspection provided no errors or measurement are made in testing the product.

Now suppose that with available instrumentation, errors of measurement are made in testing the product for acceptability, as is generally the case. We emphasize now that we do not know actually whether an item we have tested is a conforming unit or a non-conforming unit since errors of measurement are made in testing. For the above example, consider that the standard deviation of errors of measurement amounts to 0.0025 μf, which in some practical cases may be representative. (Methods for estimating precision of measurement and product variability may be found in Reference 1).

Since we are going to make errors of measurement in testing a product for acceptability, we should perhaps place test limits at places somewhat different from the specification limits in order to guard against accepting too much bad material and also against rejecting too much good material. As a natural inclination, we may, for example, want to place the test limits at say 0.100 ± 0.007 μf in order to guard against accepting "bad" or non-conforming units. If this were done we would find that of 1000 units tested 130 good units would be rejected, 825 good units accepted, 40 bad units rejected and five bad units accepted. Of the *accepted* product, 5/830 or 0.6 percent is now non-conforming and 825/830 or 99.4 percent is conforming. But this has been accomplished at the expense to the manufacturer of rejecting 130 of his good units while accepting only five bad units! This hardly seems to be a reasonable acceptance procedure because we are rejecting too much of the really accept-

able product and probably could stand to accept more non-conforming material than the small number, five, indicated.

The major point here is that in spite of the fact that practically all (95.5 percent) of the product is within specification limits the "consumer" would be rejecting 13.6 percent of the conforming units, and this would appear to be unfair, depending of course on economic grounds or the cost of accepting a bad unit compared to the cost of rejecting a good unit. It becomes clear, therefore, that precautions are necessary in setting test limits when errors of measurement are made in testing a product for acceptance.

THE PROBLEM AND PROPOSED SOLUTIONS

What principles, therefore, should be followed in placing test limits relative to specification limits? Because of errors of measurement we will misjudge some of the product presented for acceptance. On the one hand there is a chance of accepting a non-conforming unit (consumer's risk, we could say), and on the other hand we incur a chance of rejecting a conforming unit (producer's risk).* Our problem then is to minimize these errors in some way, but this introduces some difficulty because several possible criteria for "minimizing" these errors appear. Of course, one might say that such errors would not be made if the standard deviation of errors of measurement is zero or negligible compared to the product standard deviation. However, this may be impossible to obtain on practical grounds as the number of instruments required or the number of measurements may be prohibitive economically.

Criterion 1. One procedure would be to set test limits so that always the producer and consumer both suffer the *same* or *equal risks* in misjuding product. If this were done then it would be found in the above example that the test limits should be set *outside* (!) the specification limits and should be placed at $0.100 \pm 0.0103\mu f$. In this case, the producer's and consumer's risks are both about two percent, which is an improvement over the first-mentioned test limits of 0.100 ± 0.007 μf since now the number of conforming units rejected has been decreased from 130 to 20 and the number of non-conforming units accepted increased only from five to 20. In this case, as a result of this inspection 97.9 percent of the passed units are conforming and 2.1 percent non-conforming. The required probability theory for this and succeeding cases is given in the Appendix.

Table I covers the case where we impose the condition that the consumer's risk, A, and the producer's risk, B, are made equal. The following will explain the parameters used in the tables: Let σ_x denote the product variability and σ_e the standard deviation of the errors of measurement. Let k be the deviation of the specification limits from the product mean in units of σ_x. (It is assumed that the process average is midway between specification limits.) Thus the specification limits for no errors of measurement would be at $\mu \pm k\,\sigma_x$. Set $r = \sigma_x/\sigma_e$. Let b be the deviation of the test limits from the specification limits in units of σ_e. The test limits would then be set at $\mu \pm (k\,\sigma_x - b\,\sigma_e)$. Table I lists b, the equal risks A and B, and the sum (A + B) as a function of the parameters k and r. It is believed that the range of k and r considered here cover the useful cases to be found in practice.

As an example of the use of Table I, consider the problem under discussion. We have $\sigma_x = 0.0045$, $\sigma_e = 0.0025$, $k = 2$, $r = 1.80$. Entering Table I with $k = 2$ and interpolating visually for $r = 1.80$, we read $b = -0.50$, $A = B = 0.02$, $A + B = 0.04$. Our test limits would then be set outside the 0.100 ± 0.009 μf specification limits; namely, at 0.100 ± 0.0103 μf.

Criterion 2. As another criterion suppose we impose the condition that the *sum* of the consumer's and producer's risks is to be a minimum. For this case, we find that the test limits should again be placed *outside* the specification limits and at 0.100 ± 0.0118 μf. Moreover, the chance that a non-conforming unit is accepted would be three percent and only 0.6 percent that a conforming unit would be rejected. This appears to be a material improvement to the manufacturer as only six conforming units are rejected (but 30 non-conforming units accepted!). Table II covers the case where we impose the criterion that the sum of the consumer's risk and the producer's risk is to be a minimum. Values of b, A, B, and (A + B) are tabulated for various values of the parameters r and k. If we enter Table II with $k = 2$, $r = 1.80$ it will be found that the risks A and B agree with the consumer's risk and the producer's risk given above.

Criterion 3. As a final criterion suppose we would like to minimize the *cost* of making wrong decisions. Here, we would have to know the cost incurred in accepting a non-conforming unit and the cost involved in rejecting a good unit, or the ratio of these two costs. The former cost is indeed difficult to estimate, whereas the latter may simply be the cost in dollars and cents of a piece of product. In any event, the quantity we want to minimize is the cost involved in the rejection of a conforming unit times the chance of rejecting a conforming unit plus the cost incurred in accepting a non-conforming unit times the chance of accepting a non-conforming unit.

Let us assume, that for the specific problem under discussion, the cost of rejecting a good item is simply the cost of the item whereas the cost of accepting a non-conforming item is the cost of the item plus the price of another item to replace the nonserviceable one; that is to say, the cost in accepting a non-conforming item is twice the cost involved in rejecting a conforming unit. For this case, we find that again the test limits should be placed *outside* specification limits and by the amount 0.0016. Moreover, the consumer's and producer's risks now become 2.2 percent and 1.8 percent, respectively. Investigation has revealed, that the cost of accepting a non-conforming unit would have to be about at least six times as large as the cost of rejecting a conforming unit for the test limits to be placed *inside* the specification limits.*

Results of setting the test limits on intuitive grounds and under each of the three criteria discussed above are summarized in Table III.

FURTHER DISCUSSION

Concerning which of the above three criteria should be selected, it is probably true that the third one would indeed be the proper one in practice (depending on the

*It is desired to point out to the reader that in this paper the consumer's risk is defined as the chance that the item under inspection is simultaneously a "defective" unit and will be judged acceptable. In a like manner, the producer's risk here is considered to be the chance that the item under inspection is a conforming unit which is rejected. These definitions are somewhat different from the customary ones, but nevertheless appear applicable to the present screening inspection problem.

*In Mr. Eagle's problem, it apparently may be very much in order to place the test limits within the specification limits.

TABLE III—Comparison of Criteria for Setting Test Limits

$\sigma_x = 0.0045$ $\sigma_e = 0.0025$ $k = 2$ $r = 1.80$ Specification Limits $= 0.100 \pm 0.009$

Criterion	b	Test Limits	Risk A	Risk B	Results of Inspecting 1000 Units: No. Good Units Accepted	No. Bad Units Accepted	No. Good Units Rejected	No. Bad Units Rejected
Limits set on "Intuitive" Grounds	+.80	.100±.0070	.005	.130	825	5	130	40
Risks equal A = B	−.52	.100±.0103	.021	.021	934	21	21	25
Minimizing A + B	−1.11	.100±.0118	.030	.006	949	30	6	15
Minimizing Cost of Wrong Decisions $C_A = 2C_B$	−.62	.100±.0106	.022	.018	937	22	18	23
Test Limits placed at Spec. Limits	0	.100±.0090	.013	.048	907	13	48	32

particular application), although, as indicated, costs may be difficult to estimate accurately. Perhaps some idea as to whether it is necessary to use cost criteria at all can be gained by the use of Table I or Table II. Under the criterion of minimizing the sum of the consumer's risk and the producer's risk as in Table II, for example, we can look up the numerical value of these risks. Having these and a very rough estimate of the relative cost of accepting a bad item and rejecting a good item, we can compute the cost of making wrong decisions (the quantity minimized under the third criterion). If this cost is not very prohibitive, then the cost criteria need not be used. If the cost appears excessive, then an effort should be made to obtain more exact estimates of the cost of accepting a bad item and the cost of rejecting a good item, and using these costs, set new test limits under the third criterion. Lacking the required accurate cost information, or at least as an interim procedure, one may as well utilize Table II; i.e., the criterion that the sum of the producer's and consumer's risks shall be a minimum.

It should be pointed out that the tables may also be used to determine the number of independent measurements or the number of measuring instruments which must be used if the risks are to be kept to some arbitrary minimum. For example, suppose (1) we have set specification limits at $\pm 2\sigma_x$; i.e., $k = 2$, (2) we have determined that the standard error of measurement for one instrument or a single measurement is about $0.5\sigma_x$; i.e., $r = 2$, and (3) we would like the sum of the risks A and B to be ≤ 0.02. Referring to Table II, for $k = 2$ we seek the smallest value of r such that (A + B) is about 0.02. This we find is for $r = 4$. That is to say, σ_e must be less than or equal to $0.25\sigma_x$. Now the standard deviation of the *mean* of n readings (or the readings of n instruments) should therefore satisfy

$$\sigma_{\bar{e}} = \frac{\sigma_e}{\sqrt{n}}$$

where σ_e is the standard deviation of the readings from a single instrument. We are given that $\sigma_e = \frac{1}{2}\sigma_x$ and require that $\sigma_{\bar{e}}$ be less than or equal to $\frac{1}{4}\sigma_x$. Therefore we require that value of n such that

$$\frac{\frac{1}{2}\sigma_x}{\sqrt{n}} \leq \frac{1}{4}\sigma_x$$

or $n \geq 4$.

So in order to insure that the sum of the risks is less than or equal to 0.02, each piece of product should be measured at least four times or on four similar instruments and the mean of these readings used.

A similar procedure can be followed using Table I in case we wish to find how many instruments are necessary in order that (for equal consumer and producer risks) A and B will be less than some arbitrary figure.

In case there occurs a change in the value of the product variability, σ_x, and/or the standard error of measurement, σ_e, we give in the Appendix formulas for determining new test limits.

Actually, it is not absolutely necessary to have estimates of σ_x and σ_e in advance as we may have inferred. That is to say, with provisions for estimating σ_x and σ_e (as for example in Reference 1) along with the inspection, we start measuring each item and tagging it with the observed measurements. When we have finished with the inspection of a "lot," we estimate σ_x, σ_e, k, r, determine specification and test limits, and then finally go back and mark or reject those units with average measurement outside appropriate test limits. This accomplishes all parts of the inspection problem simultaneously.

Finally, discussions with representatives of several organizations and companies have indicated that some designers have, in a way, set "specification" limits by accounting in a fashion for errors of measurement. Thus, in such situations, our study, applied in reverse, would indicate where the true but unknown specification limits actually are located! It seemed logical and natural to us to approach the problem as indicated in this article.

It is clear from the foregoing discussion and the Appendix that test specification limits should practically always be placed *outside* the desired or specification limits since we do make errors of measurement—here, we side with the producer even though we may be consumers! Moreover, the problem is an important one which appears to have been neglected in the past, but nevertheless one which deserves considerable further study since perhaps on intuitive grounds wrong answers would be reached in such problems where errors of measurement are involved.

Appendix

Let x = a random normal variate which describes the true product values. The product variability is described by the standard deviation σ_x and it

will be assumed that the mean value of x, $\mathbf{E(x)}$, is zero since no generality is lost by so doing (the actual product value is then a constant μ plus x).

e = a random error of measurement. Under the assumption that the measuring instrument is properly calibrated, we will say that the errors of measurement, e, are normally distributed with zero mean and variance σ_e^2; i.e., e from $N(O,\sigma_e)$.

The *observed* measurement, y or y(x); i.e., y for a given product value x, is then $y = y(x) = x + e$, so that for a given product value x, y is normally distributed with mean x and variance σ_e^2 and e is independent of x.

Now the desired specification limits can be said to be at $\pm k\sigma_x$ about the central value μ, where k is a properly chosen normal deviate. (The process average is assumed to be at μ.) Thus, if x lies between $-k\sigma_x$ and $+k\sigma_x$ it is a "conforming" unit and such product values will perform satisfactorily in use. On the other hand, if the product value x is outside the interval $-k\sigma_x$ to $+k\sigma_x$, we have a non-conforming unit or one whose service performance will be unsatisfactory. In the absence of errors of measurement, test specification limits would, of course, be placed at $\mu - k\sigma_x$ and $\mu + k\sigma_x$.

Since, however, errors of measurement are made, then test specification limits should be placed at some distance, say $b\sigma_e$, from the normal specification or performance limits. In this connection, we will say that the test specification limits are to be placed at $-k\sigma_x + b\sigma_e$ and $+ k\sigma_x - b\sigma_e$, where our primary interest will be that of determining the factor b, since k, σ_x and σ_e will be known in advance or can be estimated.[1]

Our inspection rule will be that if the *measured value*, $y = x + e$, of the product piece falls between $-k\sigma_x + b\sigma_e$ and $+k\sigma_x - b\sigma_e$ then we accept or pass the unit, whereas if the measured value y is outside these limits we reject that product piece.

Now, in selecting an item in a random way from the lot, the chance is

$$\frac{1}{\sqrt{2\pi}\ \sigma_x}\ \varepsilon^{-x^2/2\sigma_x^2}\,dx$$

that a product value will actually lie between x and $x + dx$.

The simultaneous chance that we obtain a product value x and a measured value of x which falls within $\pm(k\sigma_x - b\sigma_e)$ is the chance that x is between x and $x + dx$ times the probability or expression

$$\frac{1}{\sqrt{2\pi}\ \sigma_e}\int_{-(k\sigma_x - b\sigma_e)}^{k\sigma_x - b\sigma_e} \varepsilon^{-(y-x)^2/2\sigma_e^2}\,dy$$

This last integral represents simply the chance that the measured value of x falls between test specification limits. Thus, the chance that a non-conforming unit will be accepted; i.e., that the unit is non-conforming and will have a measured value within test specification limits, is

$$2\int_{k\sigma_x}^{\infty}\int_{-(k\sigma_x - b\sigma_e)}^{k\sigma_x - b\sigma_e}\left[\frac{1}{\sqrt{2\pi}\ \sigma_x}\ \varepsilon^{-x^2/2\sigma_x^2}\right]\left[\frac{1}{\sqrt{2\pi}\ \sigma_e}\ \varepsilon^{-(y-x)^2/2\sigma_e^2}\right]dx\,dy \quad (1)$$

Letting $r = \sigma_x/\sigma_e$, $x = t\sigma_x$ and $y - x = s\sigma_e$, expression (1) becomes

$$A = \frac{1}{\pi}\int_{k}^{\infty}\int_{-r(k+t)+b}^{r(k-t)-b} \varepsilon^{-(t^2+s^2)/2}\,ds\,dt \quad (2)$$

which is the chance that an unacceptable or non-conforming piece of product will be accepted.

The chance that a conforming unit will be rejected is obviously

$$\int_{-k\sigma_x}^{k\sigma_x}\frac{1}{\sqrt{2\pi}\ \sigma_x}\ \varepsilon^{-x^2/2\sigma_x^2}\,dx \left\{1 - \int_{-(k\sigma_x - b\sigma_e)}^{k\sigma_x - b\sigma_e}\frac{1}{\sqrt{2\pi}\ \sigma_e}\ \varepsilon^{-(y-x)^2/2\sigma_e^2}\,dy\right\} \quad (3)$$

or

$$B = \frac{1}{\sqrt{2\pi}}\int_{-k}^{k}\varepsilon^{-t^2/2}\,dt - \frac{1}{2\pi}\int_{-k}^{k}\int_{-r(k+t)+b}^{r(k-t)-b}\varepsilon^{-(t^2+s^2)/2}\,ds\,dt \quad (4)$$

It can be shown by subtracting Eq. (2) from Eq. (4) that

$$B = A + \frac{1}{\sqrt{2\pi}}\int_{-k}^{k}\varepsilon^{-t^2/2}\,dt - \frac{1}{\sqrt{2\pi}}\int_{-\frac{kr-b}{\sqrt{1+r^2}}}^{\frac{kr-b}{\sqrt{1+r^2}}}\varepsilon^{-t^2/2}\,dt \quad (5)$$

The quantity A may be referred to as a sort of consumer's risk as it represents the average risk of accepting a non-conforming product piece. The quantity B may be referred to as the producer's risk as it represents the chance that the item under inspection is a conforming piece which will be rejected. With the average risks A and B, our problem then is to find some fair way of determining the quantity b, which in turn indicates the appropriate position for test limits.

As a criterion, suppose we impose the condition that the producer and consumer shall accept the same or equal risks in rejecting a conforming unit and in accept-

ing a non-conforming unit; i.e., producer and consumer suffer equal risks in misclassifying a product piece. Then, we set $A = B$ and this leads to

$$\frac{1}{\sqrt{2\pi}}\int_{-k}^{k} \varepsilon^{-t^2/2}\,dt = \frac{1}{\sqrt{2\pi}}\int_{\frac{kr-b}{\sqrt{1+r^2}}}^{\frac{kr+b}{\sqrt{1+r^2}}} \varepsilon^{-t^2/2}\,dt \qquad (6)$$

which yields

$$b = -k\,(\sqrt{r^2+1}-r) \qquad (7)$$

In other words, test limits should be placed *outside* specification limits when errors of measurement are made. For various values of k and r, Table I gives values of b, A, B and (A+B) under the criterion that the producer's and consumer's risk are to be equal.

If there were practical grounds for saying the consumer's risk, A, should be α times as large as the producer's risk B, then the quantity b would be determined from the equation $A = \alpha B$.

Now suppose as another criterion, we impose the condition that the *sum* of the consumer's and producer's risks is to be a minimum, and determine the quantity b on this basis. Here, we set $\frac{d}{db}(A+B) = 0$ and solve for b. This leads to the requirement

$$\frac{1}{\sqrt{2\pi}}\int_{\frac{k+rb}{\sqrt{1+r^2}}}^{\infty} \varepsilon^{-t^2/2}\,dt + \frac{1}{\sqrt{2\pi}}\int_{\frac{2r^2k+k-rb}{\sqrt{1+r^2}}}^{\infty} \varepsilon^{-t^2/2}\,dt = \frac{1}{2} \qquad (8)$$

Now since usually in practice we will have $k \geq 1.5$ and $r \geq 1$, then the second integral on the left-hand side is very nearly zero, so that Eq. (8) is closely satisfied when the lower limit $k + rb/\sqrt{1+r^2} = 0$, from which we get

$$b \cong -\frac{k}{r} \qquad (9)$$

Since the second integral of Eq. (8) will not contribute much on practical grounds until its lower limit is less than about three, then Eq. (9) will be accurate as long as $k \geq \frac{1.5}{\sqrt{1+r^2}}$ and this inequality should certainly be satisfied in cases of practical importance. Note again that b is negative and therefore that test limits are to be placed *outside* specification limits by the amount $\frac{k}{r}\sigma_e$. For various values of k and r, Table II gives values of b, A, B, and (A + B) for the criterion that we minimize the sum of the producer's and consumer's risks.

As a final criterion, suppose that the cost of rejecting a conforming item, C_B, and the cost of accepting a non-conforming unit, C_A, can be determined or measured on economic grounds. Then, we may want to minimize the unit cost, $C_AA + C_BB$, or the total cost, $NC_AA + NC_BB$, of making wrong decisions. Setting

$$\frac{d}{db}(C_AA + C_BB) = 0 \qquad (10)$$

(since N is a constant) leads to

$$\frac{1}{\sqrt{2\pi}}\int_{\frac{rb+k}{\sqrt{1+r^2}}}^{\infty} \varepsilon^{-t^2/2}dt + \frac{1}{\sqrt{2\pi}}\int_{\frac{2r^2k+k-rb}{\sqrt{1+r^2}}}^{\infty} \varepsilon^{-t^2/2}dt = \frac{C_B}{C_A+C_B} \qquad (11)$$

we thus determine b as being very nearly that value which satisfies

$$\frac{1}{\sqrt{2\pi}}\int_{\frac{rb+k}{\sqrt{1+r^2}}}^{\infty} \varepsilon^{-t^2/2}dt = \frac{C_B}{C_A+C_B} \qquad (12)$$

In this case the ratio $C_B/(C_A+C_B)$ is generally less than ½ and in many cases may be considerably less than ½, and b is negative until C_A becomes about six times as large as C_B. Therefore if C_A is greater than about $6C_B$, the test specification limits will be placed *inside* the specification limits, otherwise test limits will generally be outside specification limits.

Cases will occur in practice where the product variability, σ_x, may change to $a\sigma_x$, say, and the standard error of measurement may change to $c\sigma_e$, say, where a and c are multipliers less than, equal to, or greater than unity. Then Eq. (7) for the new b becomes

$$b' = -k\left[\sqrt{\frac{r^2}{c^2}+\frac{1}{a^2}} - \frac{r}{c}\right] \qquad (7')$$

when we impose the condition that A=B, and Eq. (9) for the new value of b becomes

$$b' = -\frac{c}{a^2}\left(\frac{k}{r}\right) \qquad (9')$$

for the condition that A+B is to be a minimum.

Finally, as a criterion not proposed above, we consider that some may argue (or there may actually exist situations where) the consumer's risk A and the producer's risk B should be weighted by the proportions or numbers of non-conforming and conforming articles, respectively. We remark here that under the definitions given in this article our consumer's risk already includes the average chance that the item under inspection is non-conforming and the producer's risk includes the average chance that the item under inspection is a conforming article. In any event, if the consumer's risk and producer's risk are further weighted by such proportions, then the test limits would in general have to be placed so far outside specification limits that the piece-by-piece inspection itself in most practical cases may just as well be dispensed with since such a proportionately large part of the presented lot is conforming! We are of the opinion that the third criterion involving costs or economic considerations is perhaps the logical choice.

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Narrow-Limit Gaging*

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INTRODUCTION

The advantages which are inherent in a program of quality control require an appreciation of its philosophy, an understanding of its techniques, and provision for competent management of the program.

The discussion in this article centers about the use of gages to guide a process. Although this is a technique, it has already touched upon philosophy—the *importance of preventing trouble* rather than waiting until after manufacture to weed out the most inferior items. And it has implied the importance of management in the quality control program; the process can be guided only if information from the gaging (or inspection) function is made available to production—in time to prevent the manufacture of subsequent defects.

A basic technique of modern quality control is the Shewhart control chart for variables. One reason for its importance is the sensitivity obtainable from averages of small samples (of measurements) in comparison with an inspection record obtained from go no-go gages (attributes). The rate at which the use of these Shewhart control charts is being recognized is accelerating rapidly; yet even so, the rate is much slower than justified by economic possibilities. Some industries have made important applications—others are interested, but hesitant.

There are different reasons for the hesitance. For example, gaging to fixed limits often requires less skill and frequently less time than does measurements in certain operations. Then too, the tradition of gaging is a habit which has been established through many years of practice in some shops even where it is entirely feasible to make measurements. In either case, if we are to accelerate the acceptance of process quality control, we must either persuade these shops to make measurements on small samples at appropriate intervals of time; or we must concede that there are real advantages to gaging and develop techniques to improve the sensitivity of go no-go data.

It is our personal intentions to use both approaches, and we will make our decisions in terms of the existing traditions and personnel in each plant, and in terms of the type of operations involved. A control chart using $\bar{X}$, R is a powerful tool. But we are impressed, too, with the sensitivity which can be obtained with Narrow-Limit gages (NL-gages) using samples comparable in size with those for $\bar{X}$, R charts. In this article we discuss some of our experiences with the use of NL-gages, and indicate enough of the theory to provide a practical basis for applications of the methods.

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GENERAL APPLICATIONS OF NARROW-LIMIT GAGES

A screw-machine shop is a typical example of an operation which can make important applications of statistical quality control. It is our experience that only a few of them have done so; many plants have spent large sums of money for automatic screw-machine lathes, but have not made adequate provision for controls. Many people are not yet familiar with the economic advantages of using even the straight-forward applications of statistical quality control.

There are many operations which use gaging techniques or variations of them. The sensitivity of a destructive test can be modified by the design; a test designed to destroy all of the items tested, or one which will destroy none of the items, does not provide a means of distinguishing between different levels of the two products. The killing of insects by insecticide; biological assay, and similar techniques; the comparison of one taste or smell with another; the comparison of one defect with another; these are all variations of go no-go gaging, and the sensitivity of their applications can usually be improved by appropriate statistical design. The techniques discussed in this article are pertinent to these objectives.

In some processes the process capability is less than the (specification) tolerances, and economics indicate that some shift in the process average can be allowed—provided we have means of detecting the approach of rejects. In other processes, the process variability is essentially equal to the tolerance spread, and *statistical control* of the process is necessary (minimum shift in process level) to minimize rejects from the process. The application of NL-gages are discussed here in reference to both types of applications.

There have been two important papers on compressed (or narrow-limit) gages, both published in England. We are indebted, particularly, to two articles for many ideas developed in this paper; one article is by Dr. B. P. Dudding and W. J. Jennett[1] and the other is by W. L. Stevens.[2]

The contributions of this present article are the following:

(1) The presentation of families of operating characteristic (OC) curves of the sampling plans.

(2) There is always a value in presenting the OC-curves for any sampling plan; here we have presented families of these OC-curves to show the effects of changes in important phases of several NL-gaging plans. These families of curves are adequate to indicate the choice of a particular NL-gaging plan in a particular application.

(3) Criteria for selecting an NL-gaging plan.

(4) An outline of the British developments in NL-gaging.

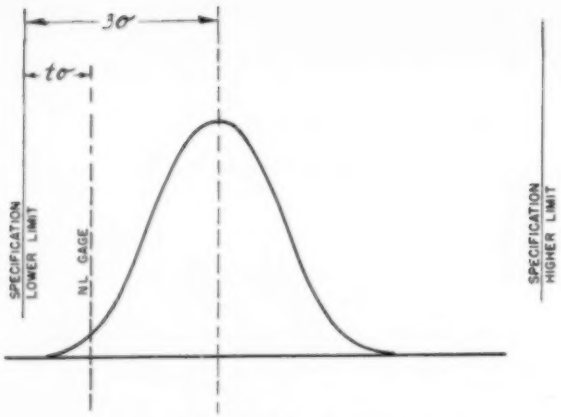


Figure 1—Definition of tσ for NL-Gage Limit

(5) A simple Vendor Instruction Manual for Shop Operations to help vendors set up NL-gaging plans.

(6) An outline of two case histories.

OUTLINE OF AN NL-GAGING PLAN

To guide manufacturing, go no-go gages are prepared which are stricter than specifications by an amount which we indicate by the symbol tσ (see Fig. 1). Then small samples (5, 10, or 20) are taken at regular intervals of time, and a record kept of the number of units which do not pass the NL-gages. (Any units which fail the NL-gages, but which pass specification gages can be sold by the company, of course.)

In our initial discussion we assume that *there are two specifications and that they are wide in comparison with the process capabilities.* (Stevens discusses, in great detail, a method of control when the process capabilities are essentially equal to the required tolerances.) We shall consider that six standard deviations (6σ) represents the process capability.

(1) The sample size, n

(2) The number of units, c, (in the sample) allowed outside an NL-gage before the process is to be adjusted

(3) The distance, tσ, which the NL-gages are moved in (compressed or narrowed) from the specifications

ESTIMATE OF PROCESS CAPABILITY

Evidently, then, an estimate of the process variability is needed before an appropriate gage can be specified. If there is a control chart history for the (controlled) process, then the evident estimate is:

$$\sigma = \bar{R}/d_2$$

where d_2 is a constant.[3] Or, we may base our estimate of σ on experience either with the particular process or machine; this experience may be personal, or it may be general trade experience.

Frequently, a satisfactory estimate of the variability can be established by a conference which includes two or three men who are familiar with the process representing production and engineering. If measuring equipment is available, then they can be used to obtain measurements on a number of items, and an estimate of the process variability. (Special gaging techniques may also be used to provide an estimate of σ.)

OPERATING CHARACTERISTIC CURVES

It is standard procedure to indicate a sampling plan by its average outgoing quality limit (AOQL), or its acceptable quality level (AQL), or its lot tolerance percent defective (p_t). The Dodge-Romig tables list both an AOQL and a p_t. The recently revised Military Standard 105-A (MIL STD 105-A) goes even farther and furnishes OC-curves for different sampling plans, and this procedure is to be recommended.

We present several different families of OC-curves corresponding to certain variations in the NL-gaging procedures. The abscissa, p, represents the percent outside of specifications; the ordinate represents the probability of "accepting," or more appropriately in process control, the probability that the process will be allowed to continue without adjustment.

A. *Effect of change in n (for fixed values of t and c).* Whenever we pick a larger sample from a lot, we expect to find more defectives; an increase in n will evidently increase the severity of our plan unless some other compensation is provided. The extent of this effect of changing n is indicated in Fig. 2 corresponding to arbitrarily selected values of t and c.

B. *Effect of change in c (for fixed values of t and n).* If we accept more items outside our NL-gages, the severity of the sampling plan will decrease. The extent of this decreasing effect is shown in Figs. 3A and 3B.

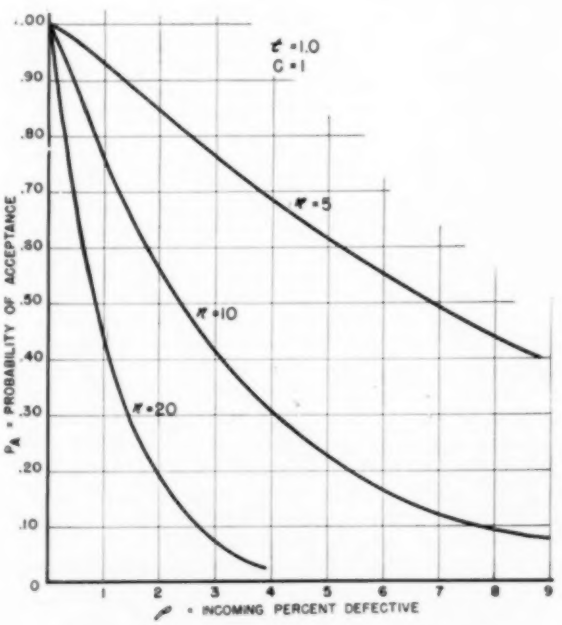
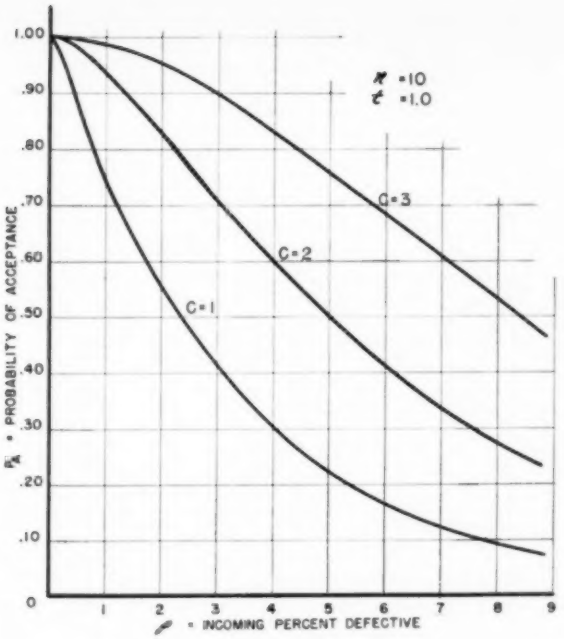


Figure 2—OC-Curves for t = 1, c = 1, n = 5, 10, 20
(Based on Binomial Distribution)



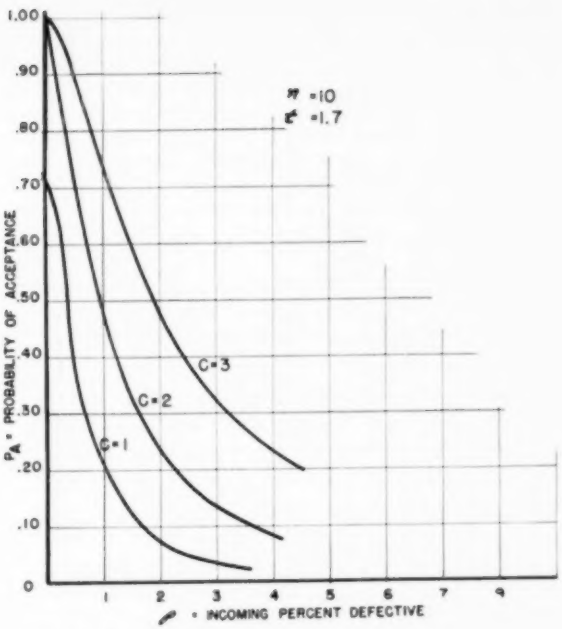


Figure 3A—OC-Curves for n = 10, t = 1, c = 1, 2, 3. Figure 3B—OC-Curves for n = 10, t = 1.7, c = 1, 2, 3.
(Based on Binomial Distribution)

C. *Effect of change in t.* As we increase t, we increase the compression of our NL-gages and consequently the severity of our sampling plan. (See Figs. 4A, 4B, 4C, and 4D.)

Dudding and Jennett designate their gages in the following way. If the gages are moved in 3σ units, then t = 3, and the gages are called 50 percent gages; if t = 1.7, they are 10 percent gages; if t = 1.5, they are 7 percent gages. They are designated by the area between the specification limit and the NL-gage limit when the process average is 3σ units inside the specification limit.

It is important to note that compressing the gages by a large amount, for example t = 1.7 or more, has a fundamental effect upon the operating characteristics at p = 0. In Fig. 3A, we see that when p = 0 the probability of resetting is 26 percent. This undesirable condition occurs because the process is producing some material which is outside the NL-gage but inside the specifications. Having to reset the process unnecessarily (i.e, at p = 0) can be avoided in either of two ways by choosing an NL-gage plan in which:

(a) we compress the NL-gage by less; for example, by t = 1.0 instead of 1.7. This reduces the probability of resetting from 26 percent to two percent when p = 0;

(b) we increase the value of c. The plan n = 10, t = 1.7, c = 3, has a probability of one percent of resetting the process when p = 0.

SELECTION OF A SIMPLE NL-GAGE SAMPLING PLAN

Most people who have worked in quality control have sometime or another used $\bar{X}$, R charts for sample sizes n = 4 or n = 5. Personally, we don't usually use larger sample sizes (not even as large as n = 9), because they indicate shifts or peculiarities in the process which aren't usually worth looking for.

Criterion A.

Those then who are familiar with $\bar{X}$, R charts, for n = 4, will have a sense of familiarity with an NL-gaging plan which has a similar OC-curve. Now in Fig. 4B and 4C, we have indicated by broken lines the OC-curves corresponding to two $\bar{X}$, R charts. Evidently there are at least three NL-gaging plans which have OC-curves almost identical with $\bar{X}$, R charts for n = 4, namely:

n = 5, c = 1, t = 1.0 (Fig. 4A)

n = 10, c = 1, t = 0.5 (Fig. 4B)

n = 10, c = 2, t = 1.0; (Fig. 4C)

If we are controlling a process with $\bar{X}$, R charts with n = 5, and we believe there is need for more information, then we usually take samples *more frequently* in preference to increasing the size of n. The same recommendation applies to the use of NL-gages, recognizing that different conditions require different solutions.

Criterion B.

The effectiveness of any of these techniques in controlling quality is improved *when we post the record of our results on control charts.* These charts frequently indicate the approach of trouble in time to take corrective action. This indication of approaching trouble would not be possible in an acceptance plan with an acceptance number of c = 0; for as soon as even one unit is found outside NL-gages, the process would have to be reset. Consequently the smallest desirable value of c, for process control purposes, would be c = 1.

Criterion C.

If we are not much concerned about resetting the process unless the process shifts quite a distance, then n = 10, t = 1.0, and c = 2 or 3 are appropriate plans. If, however, it is important to reset the process if there is even a small percent outside of specifications, perhaps n = 10, c = 1, t = 1.0 is indicated. This latter plan is a little stricter than the plan designated by MIL STD 105-A as a 1½% AQL (p. 33, Letter H).

There must always be a compromise between the producer's risk (the probability of resetting the process unnecessarily)—and the consumer's risk (the probability of *not* resetting the process when the process has shifted too far). These concepts have been developed by Harold Dodge and Harry Romig.[6]

Criterion D.

Dudding and Jennett indicate plans with large acceptance numbers; such as n = 10, t = 3.0, c = 8. In

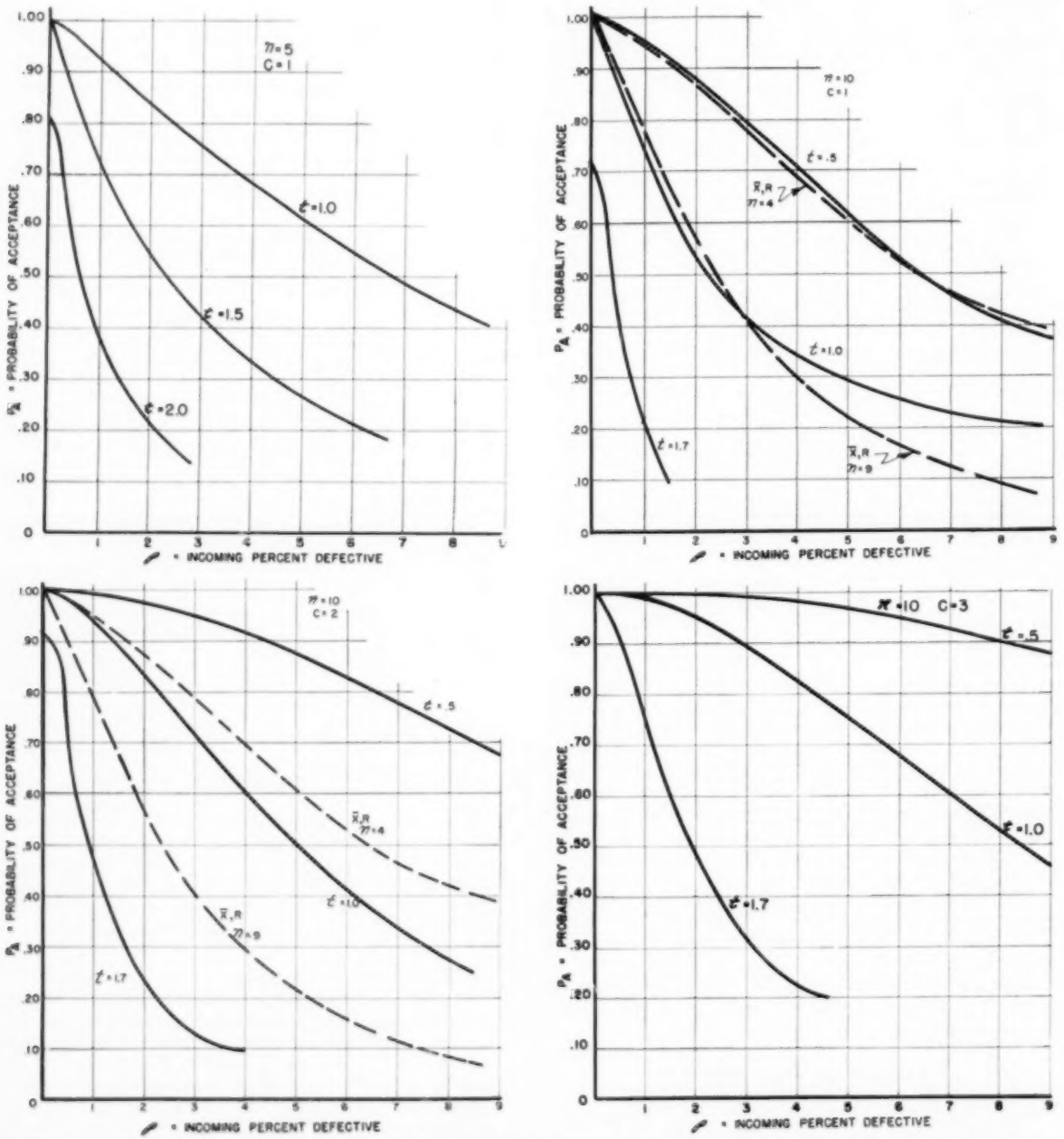
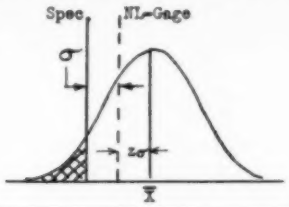


Figure 4A—OC-Curves for n = 5, c = 1, t = 1, 1.5, 2. Figure 4B—OC-Curves for n = 10, c = 1, t = 0.5, 1, 1.7. Figure 4C—OC-Curves for n = 10, c = 2, t = 0.5, 1, 1.7. Figure 4D—OC-Curves for n = 10, c = 3, t = 0.5, 1, 1.7.
(Based on Binomial Distribution)

TABLE I—Work Sheet for Computing OC-Curve of NL-Gage Plans (See Fig. 5)

Plan A: n = 5, t = 1.0, c = 2

Plan C: n = 15, t = 1.0, c = 2



Plan D: n = 15, t = 1.0, c = 3

Plan E: n = 15, t = 1.0, c = 4

% outside spec.	σ units		100 (p) % outside NL-gage	np = 5p*	Prob. of Acceptance, P_A Plan A*	np = 15p*	Plan C*	Prob. of Acceptance, P_A Plan D*	Plan E*
	1.0 + z‡	z							
0.097	3	2.0	2.27	.113	1.00	.339	.996	1.00	1.00
0.5	2.53	1.57	5.82	.291	.997	.873	.933	.987	.998
1.0	2.33	1.33	9.2	.46	.986	1.38	.833	.946	.986
1.5	2.17	1.17	12.1	.605	.977	1.81	.731	.892	.964
2	2.05	1.05	14.7	.735	.960	2.205	.623	.819	.928
3	1.88	.88	18.9	.945	.93	2.83	.469	.692	.848
4	1.75	.75	22.7	1.13	.895	3.4	.34	.558	.744
5	1.64	.64	26.1	1.30	.857	3.9	.253	.453	.648
6	1.55	.55	29.1	1.45	.825	4.3	.20	.377	.570
7	1.48	.48	31.6	1.58	.783	4.74	.152	.31	.49
8	1.41	.41	34.1	1.70	.757	5.1	.116	.251	.423
10	1.28	.28	39	1.95	.69	5.85	.67	.17	.313

‡Assumes a normal curve.
*Based on Molina's Tables (Poisson).

many cases there are psychological arguments against such large values of c—it is difficult to convince an operator that he should be "quality-minded" if you tell him that he will be allowed as many as eight units out of ten outside the gage—even an NL-gage. In such cases, a plan with a small c is evidently to be preferred.

The choice of a large value of t, such as t = 3, will in some cases mean that only one gage set at the process target is needed. In any event, almost identical OC-curves can be obtained by variations of both c and t. (See, for example, n = 10, t = 1.7, c = 3 and n = 10, t = 3.0, c = 8). A single gage set at the desired mean is equivalent to using the median of the sample to estimate the mean of a normal distribution.

Summary.

The families of OC-curves given in the accompanying figures are entirely adequate to indicate appropriate choices of n, t, and c; different combinations permit the selection of a plan tailored to the peculiarities of the particular type of industry or operation. OC-curves of $\bar{X}$, R control charts, the OC-curves of Dodge-Romig, or of MIL-STD 105-A will provide a convenient standard of comparison.

For those who like to adjust a sampling plan to fit their own particular needs, a table of computations is included as Table I. (This particular one is based on the Poisson distribution using Molina's tables.[8])

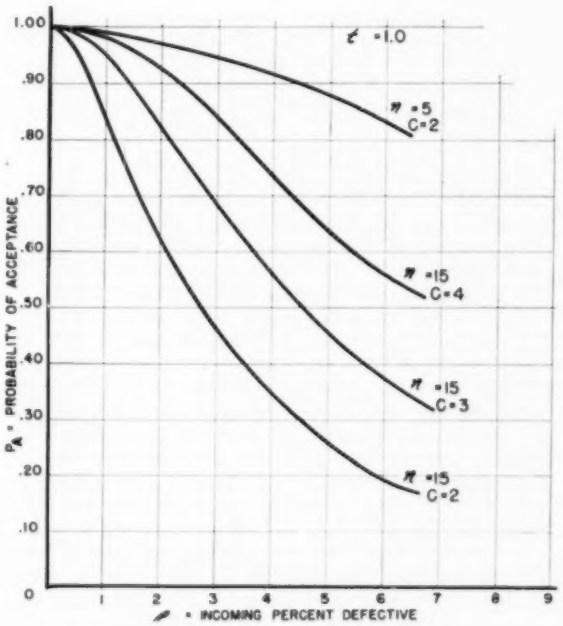


Figure 5—OC-Curves for NL-Gaging Plans Shown in Table I
(Based on Poisson Distribution)

SEQUENTIAL NL-GAGING PLANS

In the preceding section we discussed methods of selecting a simple NL-gaging plan. But before selecting one, it will be worth while to consider the effect of maintaining an *accumulated record* of the last few lots. For example, although it may be reasonable to allow one unit to be oversize in a sample of five, it may not be reasonable to permit the process to continue if three consecutive samples each contain one oversize unit.

We have presented certain OC-curves in Fig. 5; these are the curves corresponding to the different plans computed in Table I. The OC-curve listed as Plan A corresponds to (n = 5, t = 1.0, c = 2). This is not a very strict plan; we see that it will not work a hardship on production by stopping the process even if the percent of rejects is as high as three or four percent. However, it will allow the process to continue about 80 percent of the time if the percent of rejects is as high as seven or eight percent.

The severity of the operating characteristic for larger values of p can be increased by coupling two plans; for example, Plan A (n = 5, t = 1.0, c = 2) *and* Plan D (n = 15, t = 1.0, c = 3). The decision to adjust the process will then be made *either*,

(a) on the evidence of a single sample of five, *or*

(b) on the combined data of the last three samples, n = 15.

(Note: The OC-curves shown for n = 15 are slightly more liberal than the OC-curves corresponding to three successive applications of Plan A; since, for example, Plan D would permit the process to continue if there were two defects in one sample and one in another, and Plan A would not allow continuance because of the two defects.) It should be noted that the same NL-gages are used for the two parts of the sequential plan.

In practice, we have found this accumulation of evidence from successive samples to be of economic importance and easy to administer. Consequently, we have used other families of curves corresponding to n = 5, 10, 15 and 20, values of t = 1.0 and 1.7, and various selected values of c. These families may be used as plans in their own right or in conjunction with other plans. OC-curves are shown in Figs. 2-5 for certain selected combinations of n, t and c.

SHOP INSTRUCTIONS FOR OPERATING A TYPICAL NL-GAGE PLAN

Let our plan be: n = 5, c = 1 *and* n = 15, c = 2. This plan allows *one* unit outside NL-gages in any single sample of five; and allows *two* outside in the last three accumulated samples (of 15). (The operation of the plan is independent of the amount the gages have been compressed.)

A. *Set-up Procedure*

Adjust the machine or process and run five pieces.

(a) The machine is satisfactorily adjusted if all five pieces pass the NL-gages; *let the machine run.*

(b) The machine is *not* satisfactorily adjusted if any piece does not pass the NL-gages. Readjust and repeat the NL-gaging of five pieces. Repeat until all five pieces pass the NL-gages.

B. *Adjustment of Process*

Check with the NL-gages a sample of five pieces of the most recent production at regular time intervals of an hour, quarter-hour, half-hour, or every two hours, as experience indicates the need.

(a) Record the number of pieces which are *high* and the number *low* on the chart. (See Fig. 6)

(b) The machine shall be adjusted on the characteristic found to be out of the NL-gage limits when (*and only when*):

(1) *two or more* pieces fail the NL-gages on that characteristic in the last sample (n = 5, c = 1); or

(2) *three or more* pieces fail the NL-gages on that characteristic in the accumulation of the last three samples (n = 15, c = 2).

(c) Continue to operate the machine *without adjustment* unless one of the two conditions in "b" occurs.

FORMS FOR RECORDING NL-GAGE DATA

Example 1. Trays holding 25 cathodes were sprayed with an oxide coating. A critical characteristic was the thickness of the coating which was applied by 30 to 40 passes of a spray gun across the face of the nickel cathodes. It was decided to replace the control procedure which had been in use by an NL-gage procedure with the gages compressed from the upper specification and the lower specification by one sigma (t = 1.0). The plan agreed upon was: n = 5, c = 1 *and* n = 15, c = 2. The OC-curves of this plan corresponding to the single sample and the three accumulated samples are shown in Fig. 5.

From each tray of cathodes which has been sprayed, five were selected and checked with the NL-gages. The number of oversize (high) and undersize (low) cathodes were marked on the chart as in Fig. 6.

By studying the behavior of the spraying, it was soon learned when and how the process should be adjusted: by cleaning the spray guns; by increasing or decreasing the number of passes; by instructing the operator as to speed of passes; and other factors.

The improvements in this process were substantial:

1. It was possible to introduce acceptance sampling on racks of sprayed cathodes and thus eliminate a hold-up on the production line.
2. Because of rapid determination of the state of control available by go no-go gaging, the spray operator had current information to use in adjusting the process. This plan reduced the number of racks sent back for additional spray passes (cathodes undersize); and simultaneously reduced the number of cathodes which were scrapped for being oversize from an average of 20 percent to less than one percent. With less rework flowing through the production line, it was possible to reduce the inspection personnel and increase the yield of good cathodes.
3. Even more important, however, was the uniformity of the cathode thickness. Using NL-gaging, it was possible to reduce the overall spread of the sprayed cathodes by a factor of 50 percent. This improvement was so radical and so important in subsequent operations that the completed product, of which the cathodes were a sub-assembly, was improved from being mediocre to being an outstanding successful product on the market.

Example 2. NL-gages have an important application in guiding a process where measurements can be made easily even to ten-thousandths, as in a machine shop. On the part in this example the specifications were 0.2377-0.2383 in.; a nominal dimension of 0.2380 in. with a tolerance of ± 0.0003 in. It was estimated that the machine was capable of producing parts to within ± 0.0002 in.; consequently our estimate of σ is 1/6 of 0.0004 in. Convenience of measuring indicated that the limits should be compressed by 0.0001 in. which means that t = 1.5, approximately. The operator measured the

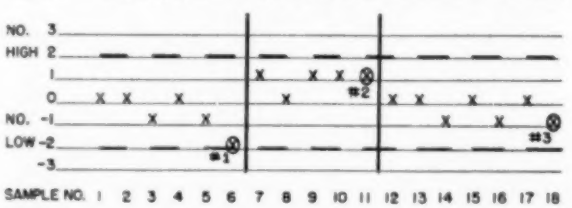


Figure 6—Plottings of NL-Gaging of Three Samples of Five Oxide-Coated Cathodes

Notes:

#1. Sprayer cleaned (fails n = 5, c = 1 criteria).

#2. No. of spray-passes reduced by four after a conference with foreman, (failed n = 15, c = 2 criteria).

#3. No. of spray-passes increased by four after a conference with foreman, (failed n = 15, c = 2 criteria).

critical dimensions with a toolmaker's micrometer and indicated by a check ($\surd$) mark the readings which he observed. These data are presented in the chart of Fig. 7, which is a combination between a variables chart and an NL-gage chart. It is a form which has been accepted and maintained by the operator of a screw machine.

Although no physical NL-gages were made for this particular machine shop application, the entire concept of process control being used was exactly that of NL-gaging. It has been our observation that some operators understand the concept of go no-go information better than they do the control chart presentation of variables data, and consequently they are better able to maintain the process at a satisfactory level of operation with NL-gages.

VENDOR INSTRUCTION PAMPHLET

We have prepared a booklet, with simplified directions for selecting and operating an NL-gaging plan, including appropriate record sheets. Although it was prepared primarily for machine operations, it has broad interpretations. Copies are available upon request.

HAZARDS

There is a potential error if our estimate of σ is incorrect—the extent of the effect can be seen from Fig. 4. If our estimate of σ is in error by 25 percent, for example, instead of operating on a curve corresponding to $t = 1.0$, we either operate on the curve corresponding to $t = 1.25$ (if our estimate of σ was too large) or we operate on the curve corresponding to $t = 0.75$ if our estimate of σ was too small. In either case, a difference of this magnitude does not appear to be an important factor.

Suppose that that portion of the distribution nearest the specification limit is not essentially normally distributed. In most instances this is more of a statistical question than a practical one—although there are notable exceptions in certain electronic characteristics, for example. We have never found enough variation from a normal distribution in machine operations to be important unless product from different heads or spindles is being combined. Although there is an effect from tool wear, that portion of the curve nearest the specification (and from which we draw our sample—the *last n consecutive pieces*) is typically normal.

If the distribution is "violently" non-normal, or if an error is made in estimating σ, the NL-gaging system

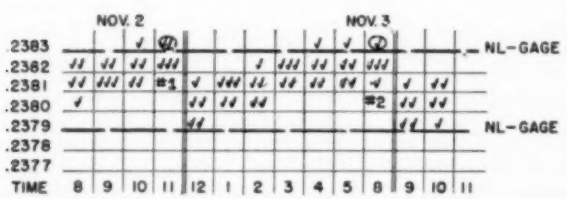


Figure 7—Control Chart on a Screw Machine Operation Using NL-Gaging Principles

Notes:
#1. Sample failed n = 5, c = 1. Tool was reset.
#2. Sample failed n = 15, c = 2. Tool was reset.

still provides control of the process but not necessarily at the predicted level.

In discussing a similar situation, Tippett [7] remarks that there need not be too much concern about whether there was an "accurate and precise statistical result, because in the complete problem there were so many other elements which could not be accurately measured."

CONTROL OF PROCESS TO A TARGET

Stevens [8] discusses the control of a process which has a single "hump near the mean" and which is "not violently asymetrical." His technique is to use two gages which are (preferably) equidistant from the mean. He counts the units in the sample of n which are:

	percent in sample	number in sample
above the upper gage	r	c
between the gages	q	b
below the lower gage	p	a

He keeps control charts on (c—a) to control the mean of his process; control limits can be obtained from the variance,

$$\sigma^2_{c-a} = n\left\{(p + r) - (p - r)^2\right\}.$$

He also keeps control charts on (c + a) to control the variability of his process. The distribution of (c + a) is given by the binomial expansion of

$$\left\{q + (p \quad r)\right\}^n$$

His control charts for (c + a) are valid even if the distribution is not normal, but he advises an adjustment for (c — a). He lists the (statistical) efficiency of different gages as follows:

	%	Ef(m) %	Ef(σ) %	Ef(m,σ) %
Maximum efficiency of estimation of mean:	p = r = 27	81	33	52
Maximum efficiency of estimation of sigma:	p = r = 7	51.5	65	58
Maximum value of Ef(m,σ)	p = q = 13	69	59	64
Recommended compromise	p = q = 20	78	46	—

CONTROL OF VARIABILITY

Many industrial process capabilities show little tendency to change. But if there is doubt about the stability of the process variability, we can make either a regular or a patrol check with a gage set at the specification limit. Then from the recorded percent outside the NL-gage and outside the spec-gage, two simultaneous linear equations can be set up and solved both for σ and for $\bar{X}$.

CONCLUSION

We do not consider that all the problems associated with NL-gages have been solved. As their use is extended into new applications, the need for additional precautions will become evident. Our applications have

not presented any substantial departure from the results predicted in this article.

We have used NL-gages in a variety of applications over the last several years. Both from experience and from the underlying theory, we find that NL-gages offer a major contribution to the guidance of industrial production processes even when it is possible to use $\bar{X}$, R charts. There are many reasons which recommend NL-gages:

(a) Gaging only is required—no measurements.

(b) The sensitivity is excellent, even for samples of five, and is comparable to the sensitivity of con-charts using samples of four and five.

(c) Record keeping is simple but effective. Charting the results at the machine is simpler and faster than with $\bar{X}$, R charts. The number of pieces which fail to pass the NL-gages can be marked on a chart by the operator himself. Trends in the process and shifts in level are often detected by the operator before the trouble is serious. Operator comprehension is often better than with $\bar{X}$, R charts and less patrol inspection is necessary.

(d) NL-gage plans may be applied in many operations where $\bar{X}$, R charts are not feasible, thereby bringing the sensitivity of $\bar{X}$, R charts to many difficult problems.

The selection of a plan is similar to deciding the sample size and sample frequency for an $\bar{X}$, R plan. In fact, the same principles must be considered.

A sample size of five is usually adequate but a sample of ten may give more assurance that the sample is really representative of the process. We recommend one of the following plans, depending upon the particular application:

$n = 5$	or	$n = 10$
$t = 1.0$		$t = 0.5$
$c = 1$		$c = 1$

These are essentially equivalent to $\bar{X}$, R charts where $n = 4$.

$n = 5$	or	$n = 10$
$t = 1.5$		$t = 1.0$
$c = 1$		$c = 1$

These are essentially equivalent to $\bar{X}$, R charts where $n = 9$. This equivalency is shown in Figs. 4A and 4C.

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Book Reviews

A. C. COHEN, Jr., *Editor*

Correspondence and suggestions concerning book reviews should be sent to:
Professor A. C. Cohen, Jr.
Department of Mathematics
University of Georgia
Athens, Ga.

ENGINEERING STATISTICS AND QUALITY CONTROL, Irving W. Burr; McGraw-Hill Book Company, Inc., New York, 1953. 442 + xi pp. $7.00. Review by E. P. King, Eli Lilly and Company, Indianapolis, Indiana.

This book is a welcome addition to the group of statistical quality control texts currently available. It gives a thorough practical treatment of process control and acceptance sampling procedures. Many examples and case histories are provided which illustrate typical spheres of application.

The author's object as stated in the Preface is to furnish "a textbook for junior, senior, and graduate students of engineering and physical science" covering topics "which have been successfully applied in the field of statistical quality control." Viewed as a text in the practical methodology of this field, Professor Burr's book is a worthwhile contribution. However it cannot be regarded as a general text in applied statistics. There are other statistical techniques of considerable importance to engineers and particularly to physical scientists which are not included in this volume. Some of these techniques require a broader background in elementary statistics than appears here. This is not intended as

an adverse criticism of the material contained. Rather, it is the reviewer's attempt to evaluate the scope of the book in relation to the author's objectives.

The first few chapters provide a general introduction to frequency distributions, descriptive statistics, and the normal distribution. The author's choice of examples and problems reflects his conscientious effort to furnish a practical setting for each new topic.

The second major portion is devoted to process control. The first of these chapters is a brief introduction to the history, purpose, and potential advantages of control chart procedures. It is short, elementary, and almost self-contained. A chapter on Control Charts for Measurements presents two distinct but related procedures—one for determining whether or not a process is in control by analysis of past data, and the other for controlling quality during production by reference to previous established standard values for the process parameters. The usual techniques for constructing $\overline{X}$, R, and σ charts are presented for each of the above situations. Their effectiveness is illustrated with case histories drawn from several types of production processes. A final chapter on measurement charts provides some of the underlying distribution theory. The material on attributes is preceded by a chapter on elementary probability which includes the binomial, Poisson, and hypergeometric distributions. A chapter on Control Charts for Attributes deals primarily with the fraction defective (p) chart and the defects per unit (c) chart. The final chapters on process control include control charts for individual measurements, slanting control limits, modified control limits, and suggestions on how and where to install control chart procedures.

The final portion of the book deals with acceptance sampling. The first chapter provides the basic structure of single- and double-sampling plans for attributes. The second chapter discusses published tables of attribute plans including the Dodge-Romig Tables, the Army Ordnance Tables, and the Military Standard 105A Tables. The first chapter on sampling by variables discusses uses of control charts and the Lot Plot Plan. The final chapter on sampling presents plans which presuppose an underlying normal distribution. For the case in which the true standard deviation is known, plans are provided which protect against too high (or too low) a mean, or both. When the true standard deviation is unknown a plan providing one-way protection is given. A plan which protects against excessive variability is also included.

Perhaps it would be in order to mention a few specific points which interested the reviewer.

In the discussion of the sample mean and sample standard deviation (Chapter 3) the author might have placed more emphasis on the usefulness of these statistics in describing the parent population and less emphasis on their usefulness "for condensing data" and giving "a one-number description of the set of data." For example, in the discussion at the bottom of page 59 it is stated that about 95 per cent of 50 "well-behaved" measurements should fall within $\overline{X}-2\sigma$ and $\overline{X}+2\sigma$ ($\overline{X}$ and σ both computed from the sample of 50). It is perhaps of interest to observe that only about three times out of four can one rest assured that an interval of this size (computed from 50 measurements) will include at least 95 per cent of the parent population (assumed normal).

The section on "Some Theory Underlying Control Charts for Measurements" (Chapter 7) might have devoted less space to detailed mathematical derivations. The mathematical reader can probably carry out these derivations unassisted, while the non-mathematical reader is apt to be interested only in the results.

The reviewer feels that the Lot Plot Plan (Chapter 14) should not be considered a general method of sampling by variables, but rather as a practical application of descriptive statistics. As originally formulated, the plan was a mixture of statistical concepts and "rule-of-thumb" procedures. Those phases which Professor Burr emphasizes are for the most part standard statistical procedures. Some of the details of the plan which the author wisely omits are of questionable value in the opinion of the reviewer.

On page 391 the author states that "In the very first exploratory fumbling of a research worker statistical methods are not applicable." The reviewer feels that one branch of applied statistics, experiment design, is specifically directed toward this exploratory work. It has been the reviewer's experience that the research worker is apt to benefit more from those statistical methods that help him plan his preliminary work efficiently than from those which aid the analysis and interpretation of his experimental results.

The general content of this book is suited to the needs of the technical worker interested in the control and evaluation of repetitive operations. The student whose practical experience is yet to come will find many examples from a wide variety of industries. These examples should not only give him a better understanding of basic statistical quality control procedures, but should also acquaint him with some types of problems he is apt to face in practice. The professional will find process control and acceptance sampling procedures presented in a "down-to-earth" manner that can be grasped in part time reading without formal instruction.

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AMERICAN SOCIETY FOR QUALITY CONTROL

EIGHTH ANNUAL CONVENTION
SAINT LOUIS, MISSOURI
JUNE 9, 10, 11, 1954

February 10, 1954

Please reply to:

Mr. Paul K. Leatherman, General Chairman
Eighth Annual A.S.Q.C. Convention
% Lambert Pharmacal Company
Saint Louis 6, Missouri

Dear Mr. Leatherman:

This is to report that the program for the Eighth Annual ASQC Convention appears to be a most excellent one.

We have received superior cooperation from speakers and moderators as well as from the officers of the various sections of ASQC who submitted so much valuable material to us.

Plans have developed to have 72 Sessions including 67 Technical Sessions and 5 Sessions devoted to Plant Tours. The Chemical and Textile Divisions are participating as are the Aircraft, Automotive, Electronics, Metals, and Operations Research Committees. In addition, the more recently organized Business Operation Committee has a program, and a series will be presented by the Basic Research Committee.

Upon the suggestion of our National Organization, your Planning Committee dropped the Basic Educational Session and the Proposed Advanced Educational Session. It is intended that these materials will be integrated with those above.

Special thanks are due Mr. John G. Rutherford who as National Program Chairman has issued the official instructions to the speakers and the moderators.

Respectfully submitted,

Lloyd A. Knowler

Lloyd A. Knowler

LAK:bb

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AMERICAN SOCIETY FOR QUALITY CONTROL

EIGHTH ANNUAL CONVENTION
SAINT LOUIS, MISSOURI
JUNE 9, 10, 11, 1954

Please reply to:

February 1, 1954

Mr. Paul Leatherman,
General Chairman
8th Annual Convention

Dear Paul:

Plans of the Special Events Committee are all made and we are pleased to report that we have an outstanding program arranged.

Some of the highlights of this program are:

PLANT TOURS - Many plant tours are being made available for convention guests every afternoon. During these afternoons plant tours will be available at the Chevrolet Plant, Continental Can, Century Electric (motors), Elder Manufacturing Company (shirts), Magic Chef, Carter Carburetor, Anheuser Busch and Falstaff Breweries.

SOCIAL NIGHTS - We are particularly fortunate in that Anheuser Busch has invited us to a Pre-Convention Social Evening on Tuesday evening. The Social Evening scheduled for Wednesday will be a surprise package. Due to the nature of what we are planning, we cannot reveal anything at this time.

ADDITIONAL ENTERTAINMENT - A Special Events Booth will have tickets available for other social events including:

St. Louis Cardinal Ball Games
St. Louis Municipal Opera
Steamer Admiral for trips on the Mississippi
Golden Rod "Showboat" for old time melodrama

Sincerely yours,

Henry O. Schott

Henry O. Schott

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AMERICAN SOCIETY FOR QUALITY CONTROL

EIGHTH ANNUAL CONVENTION
SAINT LOUIS, MISSOURI
JUNE 9, 10, 11, 1954

January 27, 1954

Please reply to:

Mr. Paul K. Leatherman
General Chairman
Eighth National Convention
American Society for Quality Control

Dear Paul:

Our plans for the Book Booth at the Convention in June have been finalized. I feel that we can offer our Guests a pleasant and unique experience. Actually, as you know, our Book Booth will consist essentially of a lounge area equipped with comfortable chairs and divans, adequately lighted, and recessed from the main exhibit area. We should like to give our guests the opportunity to relax, and to browse through as many as they can of the fine works we shall have available.

Of course we shall continue the practice of past years in having authors present during scheduled periods to meet with those interested in particular works, or merely interested in general discussions of an informal nature. We should like to encourage the sales of our books. However, we do feel that a lounge area where Society Members and Guests can leisurely review the literature available in their field is a feature that we are happy to offer.

I am sure our arrangements will fulfill your hopes, and ours, that every detail of the Eighth National Convention will concern itself with the comfort and enjoyment of our Guests.

Sincerely,

Joseph Movshin
Chairman, Book Exhibits

JM:MS

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AMERICAN SOCIETY FOR QUALITY CONTROL

EIGHTH ANNUAL CONVENTION
SAINT LOUIS, MISSOURI
JUNE 9, 10, 11, 1954

January 22, 1954

Please reply to:

To: General Chairman
8th A.S.Q.C. CONVENTION

Subject: Ladies Program

Will you please convey to the members of A.S.Q.C., who we hope will "Tell their wives", our plans for the ladies.

First: Tuesday evening we are invited to go along with the men to the Anheuser-Busch pre-convention Social evening.

Second: A "Kaffee Klatsch", every morning with a style show added on Thursday A.M. and a "Sunny California" Friday A.M.

Third: A guided tour of the city Wednesday A.M., including the famed St. Louis Chimpanzee Show and Luncheon. And in the evening the grand mixer with a big Surprise!

Fourth: A planned social hour Thursday afternoon with another surprise for the ladies, also the Annual Banquet for those who wish to attend on Thursday evening.

Fifth: On Thursday and Friday evenings, for those looking for entertainment, tickets will be available for any of the following: The Muny Opera, under the Stars; the S. S. Admiral Cruise on the Mississippi, or 'Ole Time Melodrama on the "Show Boat".

We've laid big plans for the women, so plan early, come early, and stay late.

Respectfully,

Dorothy C. Leatherman
Chairman, Ladies Program

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8TH NATIONAL ASQC CONVENTION TECHNICAL SESSIONS

SERIES	A	B	C	D
PERIOD 1	Theme: **General Interest.** Moderator: H. J. BECKER, American Steel & Wire Co., Waukegan, Ill. Speaker: WAYNE M. BIKLEN, Quality Control Manager, American Safety Razor Corp., Brooklyn 1, N. Y. Subject: CAN INCENTIVES AND QUALITY LIVE TOGETHER? Speaker: SOLOMON BARKIN, Director of Research, Textile Workers Union of America, (CIO), 99 University Place, New York 3, N. Y. Subject: UNION INTEREST IN QUALITY CONTROL.	Theme: **Armed Services.** Moderator: ROBERT M. HOFSTEAD, Bristol Laboratories, Inc., P. O. Box 657, Syracuse, N. Y. Speaker: LT. COL. RALPH M. LOCKHART, Office of Ass't Secretary of Defense, (Supply & Logistics), Washington 25, D. C. Subject: THE DEPARTMENT OF DEFENSE INSPECTION PROGRAM. Speaker: CAPT. B. L. LUBELSKY, U.S.N., Naval Ammunition Depot, McAlester, Okla. Subject: QUALITY CONTROL IN ORDNANCE PRODUCTION	Theme: **Aircraft.** Moderator: C. A. COVINGTON, Manager of Quality Control, Convair, San Diego 12, Calif. Speaker: W. C. HITT, Ass't. Chief of Quality Control, Douglas Aircraft, Sta Monica, Calif. Subject: NON-DESTRUCTIVE TESTING AND INSPECTION. Moderator: W. L. HUMPHREY, Quality Manager, Bell Aircraft Corp., Fort Worth, Texas. Speaker: DAVID A. HILL, Director of Quality Control, Hughes Aircraft, Culver City, Calif. Subject: RECEIVING INSPECTION METHODS AND A RELATED SYSTEM OF REPORTING VENDOR QUALITY PERFORMANCE TO TOP MANAGEMENT.	Theme: **Business Operations.** Moderator: CHARLES A. BICKING, Office of Chief of Ordnance, Washington 25, D. C. Speaker: WINSTON C. DALLECK, Quality Control Program Director, United Air Lines, Inc., 5959 South Cicero Avenue, Chicago, Ill. Subject: STATISTICAL QUALITY CONTROL AT WORK IN AIRLINE ACCOUNTING. Moderator: HOWARD L. JONES, Illinois Bell Telephone Company, Chicago, Ill. Speaker: ROBERT B. SELOVER, Director of Personnel Research, The Prudential Insurance Company of America, Newark, N. J. Subject: SQC IN OFFICE PROCEDURES AND CLERICAL WORK.
2	Theme: **General Interest.** Moderator: WARREN R. PURCELL, Rath & Strong, Inc., 80 Federal Street, Boston, Mass. Speaker: W. E. JONES, Quality Control Consultant, Management Controls, 699 Rose Ave., Des Plaines, Ill. Subject: INSTALLATION OF A QUALITY CONTROL SYSTEM. Speaker: ERVIN E. SCHIESEL, The Mattatuck Manufacturing Co., Waterbury 20, Conn. Subject: ENGINEERING STANDARDS AND TOLERANCES.	Theme: **Mechanical Assembly and Automotive.** Moderator: A. C. NORRIS, Director-Quality Control, Hudson Motor Car Co., Detroit 15, Mich. Speaker: PAUL A. ROBERT, Technical Ass't to Quality Manager, IBM Corporation, Plant I, Endicott, N. Y. Subject: QUALITY PROCEDURES PERTAINING TO COMPLEX ASSEMBLIES. Speaker: FRANCIS E. JOLLIFFE, Supervisor of Inspection, Warner Gear Division, Borg-Warner Corporation, 1106 E. Seymour Street, Muncie, Ind. Subject: QUALITY CONTROL AT WARNER GEAR.	Theme: **Aircraft.** Moderator: J. I. NESTEL, Director Of Quality Control, Avien-Knickerbocker, Woodside, N.Y. Panel: RICHARD W. TAYLOR, Project Test Pilot, Boeing Aircraft, Wichita, Kan. ROBERT C. LITTLE, Chief Test Pilot, McDonnell Aircraft Corp., St. Louis, Mo. JOSEPH ANGELONE, Staff Exp. Pilot, Chance-Vought Aircraft, Dallas, Texas. Subject: THE TEST PILOT'S ROLE IN QUALITY CONTROL. Moderator: JAMES C. McKELVAIN, Director of Quality Control, Temco Aircraft Corp., Dallas, Texas. Speaker: W. W. WILCOX, Manager of Inspection & Quality Control, United Airlines, P. O. Box 3000, So. San Francisco, Calif. Co-authored by: ALLEN M. HULL, Supervisor of Maintenance Analysis. Subject: STATISTICAL QUALITY CONTROL APPLICATION FOR IMPROVING AIRCRAFT & ENGINE MAINTENANCE.	Theme: **Business Operations.** Moderator: DALE L. LOBSINGER, Supt. Management Controls, United Air Lines, Denver 7, Colo. Speaker: GUY G. PARKIN, Director Industrial Statistical Control, Minnesota Mining & Manufacturing Co., 900 Fauquier Avenue, St. Paul 6, Minn. Subject: STATISTICAL TECHNIQUES IN PURCHASING, SCHEDULING AND SALES. Moderator: HARMON S. BAYER, Quality Control Consultant, 1154 Book Building, Detroit 26, Mich. Speaker: E. T. MACRUDER, Statistician, The Chesapeake & Potomac Telephone Companies, 725 Thirteenth St., N.W., Washington, D. C. Subject: STATISTICAL METHODS FOR APPRAISING PUBLIC UTILITY PROPERTY.
3	Theme: **General Interest.** Moderator: HARRY C. ROMIC, Hughes Aircraft, Culver City, Calif. Speaker: WILLIAM H. LESSER, JR., Supervisor of Quality Control, General Electric Company, One River Road, Schenectady 5, N. Y. Subject: COST OF QUALITY. Subject: JAMES ARMSTRONG, JR., Statistical Engineer, E. I. DuPont De Nemours & Company, Inc., P. O. Box 1477, Richmond 12, Va. Subject: SOME USES OF STATISTICS IN PLANT MAINTENANCE.	Theme: **Automotive.** Moderator: J. C. KNAPP, Superintendent Quality Control Ford Motor of Canada, Windsor, Ont. Speaker: J. S. McNALLY, Material Quality Section, Ford Motor Co., Dearborn, Mich. Subject: RECEIVING INSPECTION SYSTEMS. Panel: LEO R. HARRINGTON, Chief Inspector, King-Seeley Corp., Ann Arbor, Mich. HARRY HAUSMAN, Chief Inspector, Budd Company, Gary, Ind. NELSON G. MEACLEY, Manager Statistical Quality Control, Willys Motors, Inc., Toledo 1, Ohio. JOSEPH P. ROCHE, Chief, Quality Control Branch, National Tank—Automotive Inspection Office, Ordnance Corps, Detroit Arsenal, Center Line, Mich. Subject: VENDOR CERTIFICATION OF QUALITY.	Theme: **Aircraft.** Moderator: H. O. WILLIAMS, Chief, Quality Control, Douglas Aircraft, Sta Monica, Calif. Speaker: COLONEL CARL F. DAMBERG, USAF, Chief, Quality Control Hq., AMC, Wright-Patterson AFB, Dayton, Ohio. Subject: THE AIR FORCE QUALITY CONTROL PLAN FOR PROCUREMENT. Moderator: JOSEPH R. SILVERMAN, Quality Control Manager, Chance-Vought Aircraft, Inc., P. O. Box 5907, Dallas, Texas. Speaker: RALPH S. READE, Chief of Engineering, Test Laboratory, Consolidated Vultee Aircraft Corp. Fort Worth, Texas. Subject: ESTABLISHMENT OF QUALITY LEVEL THROUCH COMPONENT AND SYSTEM TESTING . . . AIRCRAFT SYSTEMS AND COMPLEX ITEMS.	Theme: **Business Operations and Complex Ordnance Assemblies.** Moderator: DR. CARL E. NOBLE, Kimberly Clark Corporation, Neenah, Wis. Speaker: MELVIN J. BROWN, Mgr. Control Section, National Reporting Dept., Dun & Bradstreet, Inc., 99 Church Street, New York 8, N. Y. Subject: APPLYING QUALITY CONTROL TO CREDIT REPORTING. Speaker: MAJOR GENERAL LESLIE E. SIMON, Assistant Chief of Ordnance, Washington 25, D. C. Subject: QUALITY CONTROL IN THE MANUFACTURE OF COMPLEX ASSEMBLIES.
4	Theme: **General Interest.** Moderator: PROFESSOR JOHN A. HENRY, Department of Mechanical Engineering, University of Illinois, Urbana, Ill. Panel: DR. CARL E. NOBLE, Technical Research Laboratories, Kimberly-Clark Corp., Neenah, Wis. RUDOLPH FREEDMAN, Production Superintendant, Alco Valve Co., St. Louis, Mo. FRED J. HALTON, JR., Ass't to the President, Deere & Co., Chicago, Ill. Subject: SYMPOSIUM ON INPLANT TRAINING FOR DESIGN ENGINEERS & RESEARCH WORKERS; PRODUCTION SUPERVISION; TOP MANAGEMENT.	Theme: **Automotive.** Moderator: DR. C. C. CRAIG, University of Michigan, Ann Arbor, Mich. Speaker: ARTHUR BENDER, JR., Delco-Remy Division, General Motors Corporation, 2401 Columbus Avenue, Anderson, Ind. Subject: USE OF PROBABILITY PAPER. Speaker: JAMES V. STRELA, Staff Statistician, Thompson Products, Inc., 23555 Euclid Avenue, Cleveland 17, Ohio. Subject: STATISTICAL CONTROL OF MULTIPLE OPERATIONS.	Theme: **Textile.** Moderator: CARDINER HAILES, Avondale Mills, Sylacauga, Ala. Speaker: CHARLES C. WILSON, Ass't Director, Research Division, West Point Manufacturing Company, Shawmut, Ala. Subject: TEXTILE QUALITY ANALYSIS. Speaker: ROBERT A. POSEY, Quality Control Manager, Peter Pan Manufacturing Corp., 255 Grant Ave., East Newark, N. J. Subject: QUALITY CONTROL IN CARMENT MANUFACTURING.	Theme: **New Statistical Developments.** Moderator: R. H. STEWART, Quality Manager, Lear, Inc., Grand Rapids, Mich. Speaker: CALVIN J. KIRCHEN, Rec. Insp. Quality Analyst, Wayne Assembly Plant, Lincoln-Mercury Division, Ford Motor Co., Wayne, Mich. Subject: BINOMIAL PROBABILITY TABLES. Speaker: DORIAN SHAININ, Industrial Consultant, Rath & Strong, Inc., Boston, Mass. Subject: CHART CONTROL WITHOUT CHARTS—SIMPLE, EFFECTIVE COMPARATOR QUALITY PRE-CONTROL.
5	Theme: **General Interest.** Moderator: PROFESSOR ACHESON DUNCAN, The Johns Hopkins University, Charles Street, Baltimore, Md. Speaker: PROFESSOR PAUL C. CLIFFORD, State Teachers College, Montclair, N. J. Subject: VISUAL AIDS TELL THE QUALITY CONTROL STORY.	Theme: **Statistical Analysis.** Moderator: LEO J. JACOBSON, Mgr. Q. C. Dept., International Resistance Company, Philadelphia 8, Pennsylvania. Speaker: FRANK PROSCHAN, Manager-Quality Control, Sylvania Electric Products, Inc., Hicksville, N. Y. Subject: EXPERIMENTS COMPARING TWO METHODS FOR PERCENTAGE DEFECTIVE.	Theme: **General Interest.** Moderator: PROFESSOR J. M. JURAN, 195 Beech Street, Tuckahoe, N. Y. Speaker: J. LESLIE LENTON, Works Manager, American Machine & Foundry Co., P. O. Box 187, Station F, Buffalo 12, N. Y. Subject: QUALITY CONTROL LOOKS AT THE FINANCIAL STATEMENT.	Theme: **Food Industry.** Moderator: H. J. JACOBSON, Chief Inspector, Crand Sheet Metals Products Co., Chicago, Ill. Speaker: FRED W. RUSSE, JR. Ass't Chief of the Quality Control Division, Bureau of Ordnance, Washington, D. C. Subject: DESIGN, DEVELOPMENT AND PRODUCTION WITH RELATION TO ACCEPTANCE INSPECTION PRACTICES.

SERIES	E	F	G	H
PERIOD	Theme: **Metals Inspection.** Moderator: JOHN W. W. SULLIVAN, Metallurgical Engineer, American Iron & Steel Institute, 350 Fifth Avenue, New York 1, N. Y. Speaker: FRANK G. NORRIS, Wheeling Steel Corporation, Steubenville, Ohio. Subject: SURVEY OF STATISTICAL METHODS IN THE METALS INDUSTRY.	Theme: **Operations Research.** Moderator: PAUL S. OLMSTEAD, Bell Telephone Laboratories, Whippany, N. J. Speaker: DR. HAROLD O. DAVIDSON, The Johns-Hopkins University, Operations Research Office, 6410 Connecticut Avenue, Chevy Chase, Md. Subject: OPERATIONS RESEARCH CONCEPTS USEFUL IN QUALITY CONTROL.	Theme: **Paper and Printing.** Moderator: L. S. EICHELBERGER, Quality Control Staff, A. O. Smith Corp., Milwaukee 1, Wis. Speaker: EDWARD R. HOFFMAN, Statistical Quality Control, Hammermill Paper Company, Erie 6, Pa. Subject: THE HAMMERMILL QUALITY STORY.	Theme: **Plant Tour.** Anheuser-Busch Inc., Century Electric Co., Falstaff Brewing Corp.
1	Moderator: RICHARD H. EDE, Process Metallurgist, United States Steel Corp., 208 South LaSalle Street, Chicago 90, Ill. Speaker: ARTHUR P. WOODS, JR., Research Engineer, Armco Steel Corp., Middletown, Ohio. Subject: STATISTICAL METHODS APPLIED TO STEEL PLANT OPERATING DATA.	Moderator: DR. HAROLD O. DAVIDSON. Speaker: PAUL S. OLMSTEAD. Subject: QUALITY CONTROL CONCEPTS USEFUL IN OPERATIONS RESEARCH.	Speaker: W. A. MACCREHAN, Quality Engineer, Bendix Radio, Baltimore 4, Md. Subject: QUALITY CONTROL IN PRINTING.	
2	Theme: **Metals Inspection.** Moderator: J. R. BEHRMAN, Alan Wood Steel Company, Conshohocken, Pa. Speaker: W. T. ROGERS, National Tube, Division of the U. S. Steel Corp., East 28th St. and Pearl Avenue, Lorain, Ohio. Subject: CONTROL OF QUALITY STEEL TUBULAR PRODUCTS. Moderator: RUSSELL Y. BARNES, Aluminum Company of America, Atlantic Street, Bridgeport 4, Conn. Speaker: ALLIN P. DEACON, P. Eng., Cockshutt Farm Equipment, Ltd., Brantford, Ont. Subject: CONTROL OF QUALITY IN A JOBBING FOUNDRY.	Theme: **Chemical—Experimental Designs.** Moderator: EDWIN C. HARRINGTON, JR., Industrial Statistician, Plastics Division, Monsanto Chemical Co., Springfield, Mass. Speaker: DONALD S. VILLARS, Research Scientist, U. S. Naval Ordnance Test Station, Inyokern, China Lake, Calif. Subject: REPLICATION DECENERACY. Speaker: CUTHBERT DANIEL, Engineering Statistician, 116 Pinehurst Avenue, New York 33, N. Y. Subject: LOCATING & MEASURING THE EFFECTS OF ASSIGNABLE CAUSES.	Theme: **Electronics.** Moderator: IRVIN W. SCHOENINGER, Globe-Union, Inc., 900 East Keefe Avenue, Milwaukee 1, Wis. Speaker: FRANK CAPLAN, JR., Supervisor-Process Quality Control, General Electric Company, Syracuse, N. Y. Subject: STATISTICAL DESIGN IN ELECTRONICS PRODUCTION-LINE EXPERIMENTATION. Speaker: LEO J. JACOBSON, Mgr. Quality Control Dept., International Resistance Company, 401 North Broad Street, Philadelphia 8, Pa. Subject: SOME CONSIDERATIONS IN THE EVALUATION OF ELECTRONIC COMPONENTS WITH SPECIAL REFERENCE TO RESISTORS.	Theme: **Advanced Theory Sessions.** Moderator: PROFESSOR IRVING W. BURR, Purdue University, Lafayette, Ind. Speaker: "To be announced". Subject: AN INTRODUCTION TO ANALYSIS OF VARIANCE. Speaker: "To be announced". Subject: COMPONENTS OF VARIANCE AND MIXED MODELS.
3	Theme: **Metals Inspection.** Moderator: NORMAN R. MOSS, Firth Sterling Steel & Carbide, McKeesport, Pa. Speaker: HAROLD L. SPRINGER, Metallurgical Analyst, St. Joseph Lead Co., Box 97, Monaca 7, Pa. Subject: QUALITY CONTROL IN THE MANUFACTURE OF ZINC—TECHNIQUE OF APPROXIMATING A THREE-VARIABLE PROBLEM SOLUTION. Moderator: JOHN F. OCCASIONE, Staff Metallurgical Engineer, American Steel & Wire, Division of United States Steel Corp., Rockefeller Building, Cleveland 13, Ohio. Speaker: LEON W. THELIN, Quality Supervisor, Chase Brass & Copper Company, Waterbury, Conn. Subject: CONTROL OF QUALITY OF BRASS STRIP.	Theme: **Chemical—Analytical Precision and Specifications.** Moderator: PROFESSOR E. R. OTT, Rutgers University, New Brunswick, N. J. Speaker: RAYMOND L. THATCHER, Manager Quality Control Division, E. R. Squibb & Sons, Division of Mathieson Chemical Corp., Georges Road, New Brunswick, N. J. Subject: VARIABILITY PROBLEMS IN THE PHARMACEUTICAL INDUSTRY. Speaker: MAYNARD S. RENNER, Dewey and Almy Chemical Co., 62 Whittemore Avenue, Cambridge 40, Mass. Subject: THE ROLE OF STATISTICAL QUALITY CONTROL IN TODAY'S CHEMICAL COMPANY.	Theme: **Electronics.** Moderator: N. E. KING, 408 Beachwood Road, Alexandria, Va. Speaker: THOMAS LUCAS, Centralab Radio Products, 900 East Keefe Avenue, Milwaukee 1, Wis. Subject: FREQUENCY DISTRIBUTION ANALYSIS OF TIME STUDY DATA ON PRINTED CIRCUITS. Speaker: NELLO CODA, Chief Electrical Engineer, Erie Resistor Corp., Erie 6, Pa. Subject: A CHIEF ENGINEER EVALUATES STATISTICAL METHODS.	Theme: **Plant Tour.** Anheuser-Busch, Inc., Century Electric Co., Chevrolet-St. Louis Division General Motors Corp., Continental Can Co., Inc., Elder Manufacturing Company, Falstaff Brewing Corp.
4	Theme: **Metals Inspection.** Moderator: D. H. W. ALLAN, Metallurgical Department, The Steel Company of Canada, Limited, Hamilton, Ont. Speaker: WALTER HAYTER, Youngstown Sheet & Tube Co., So. Chicago, Ill. Subject: CONTROL OF QUALITY OF TIN PLATE. Moderator: PHILLIPS WHIDDEN, Staff Statistician, Aluminum Company of America, Pittsburgh 19, Pa. Speaker: SAUL GILBERT, United States Steel Corp., Research & Development Laboratory, 234 Atwood Street, Pittsburgh 13, Pa. Subject: APPLICATIONS OF STATISTICAL DESIGNS TO RESEARCH PROBLEMS FOR THE STEEL INDUSTRY.	Theme: **Chemical—Continuous Processes—Sampling & Control.** Moderator: C. A. BICKING, Department of Army, Washington, D. C. Speaker: DR. JOHN T. WALTER, School of Business Administration, University of Pittsburgh, Pittsburgh 13. Subject: STATISTICAL QUALITY CONTROL IN A PETROLEUM REFINERY. Speaker: DR. W. H. WHITE, Research Department, Imperial Oil Limited, Sarnia, Ont. Subject: APPLICATIONS OF STATISTICAL METHODS TO THE CONTROL OF REFINERY OPERATIONS.	Theme: **Precision Manufacturing.** Moderator: WILLIAM E. SPENCER, Allison Division of G.M.C., Indianapolis 6, Ind. Speaker: E. J. SCHALLER, Inspection Manager, Elgin National Watch Company, Lincoln Division, 900 North 16th Street, Lincoln 1, Neb. Subject: QUALITY CONTROL IN PRECISION MANUFACTURING. Speaker: CHARLES J. HUDSON, Quality Consultant, Miniature Precision Bearings, Inc., Keene, N. H. Subject: QUALITY CONTROL IN MINIATURE BEARING MANUFACTURING.	Theme: **Advanced Theory Sessions.** Moderator: PROFESSOR IRVING W. BURR, Purdue University, Lafayette, Ind. Speaker: "To be announced". Subject: CONFOUNDING AND FRACTIONAL REPLICATION. Speaker: "To be announced". Subject: ANALYSIS OF COVARIANCE.
5	Theme: **Metals Testing.** Moderator: EDWARD B. HADEN, Quality Control Manager, The Esterbrook Pen Co., Camden 1, N. J. Speaker: V. E. LYSACHT, Sales Manager, Wilson Mechanical Instrument Division, American Chain & Cable Company, Inc., Bridgeport, Conn. Subject: HARDNESS TESTING.	Theme: **Chemical—Batch Processes—Sampling and Control.** Moderator: DR. CARL E. NOBLE, Technical Research Laboratories, Kimberly-Clark Corporation, Neenah, Wis. Speaker: JOHN D. HINCHEN, Quality Supervisor, Plastics Division, Monsanto Chemical Company, P. O. Box 1531, Springfield 2, Mass. Subject: CORRELATION ANALYSIS IN BATCH PROCESS CONTROL.	Theme: **Business Operations.** Moderator: MARTIN A. BRUMBAUCH, Director of Statistics, Bristol Laboratories, Inc., Syracuse 1, N. Y. Speaker: CLAUDE S. BRINEGAR, Union Oil Company, 617 West Seventh Street, Los Angeles, Calif. Subject: DEPARTMENT STORE USES OF STATISTICAL QUALITY CONTROL.	Theme: **Plant Tour.** Carter Carburetor Corp., Century Electric Co., Chevrolet-St. Louis Division General Motors Corp., Elder Manufacturing Company, Magic Chef, Inc.

SCHEDULE OF COMMITTEE MEETINGS

TUESDAY, JUNE 8, 1954

Operating and Executive Committees..9:00 A.M.—Jefferson

WEDNESDAY, JUNE 9, 1954

Division & Technical Committee Chairmen .....9:00 A.M.—Auditorium
Comm. on Relations with Tech. Societies .....9:00 A.M.—Auditorium
Presidential Management Award Committee .....9:00 A.M.—Auditorium
Committee on Dues Structure.....2:30 P.M.—Auditorium
Chemical Division .....2:30 P.M.—Auditoruim
Regional Conferences Committee.....2:30 P.M.—Auditorium
Annual Meeting of the Society.....4:00 P.M.—Auditorium
Chairmen of Section Administration Committee .....7:30 P.M.—Jefferson
Editorial Board .....7:30 P.M.—Jefferson
Auditing Committee .....7:30 P.M.—Jefferson
Financial Advisory Committee .....7:30 P.M.—Jefferson
Section Affairs Committee .....7:30 P.M.—Jefferson

THURSDAY, JUNE 10, 1954

Operations Research Committee.....9:00 A.M.—Auditorium
1954-55 Board of Directors.....3:00 P.M.—Jefferson
Annual Society Banquet .....6:15 P.M.—Jefferson
"New" 1954-55 Operating & Executive Committees .....9:00 P.M.—Jefferson
Professional Ethics Committee .....9:00 P.M.—Jefferson
Membership Committee .....9:00 P.M.—Jefferson
Film Library Committee.....9:00 P.M.—Jefferson
Program & Speakers Committee.....9:00 P.M.—Jefferson
Publicity & Promotion Committee.....9:00 P.M.—Jefferson

FRIDAY, JUNE 11, 1954

Membership Roster Committee.....8:30 A.M.—Auditorium
Business Administration Committee..9:00 A.M.—Auditorium
Electronics Technical Committee.....9:00 A.M.—Auditorium
Aircraft Technical Committee.....9:00 A.M.—Auditorium
Both 1953-54 and 1954-55 Boards of Directors Meeting .....3:00 P.M.—Statler
Banquet .....6:00 P.M.—Statler
Textile Division .....4:00 P.M.—Auditorium
Automotive Technical Committee....4:00 P.M.—Auditorium
Standards Committee .....4:00 P.M.—Auditorium
Education & Training Committee.....4:00 P.M.—Auditorium
Examining Committee .....4:00 P.M.—Statler
Constitution & By-Laws Committee.....5:00 P.M.—Statler

SATURDAY, JUNE 12, 1954

General Convention Committee.....9:00 A.M.—Jefferson
Metals Technical Committee.....9:00 A.M.—Jefferson
Section Administration Chairmen.....9:00 A.M.—Jefferson (all committees under Paul Robert)
Division & Technical Comm. Chairmen.9:00 A.M.—Jefferson (all committees under Julian Toulouse and Comm. on Tech. Societies Relations)
1954-55 Operating & Executive Committees .....12:30 P.M.—Jefferson

PREVIEW OF EXHIBITS

Booth 3

JOHNSON GAGE COMPANY

The Johnson Gage Company will exhibit their complete line of screw thread gages and comparators. This line of gages covers the entire field of both fixed and indicating types, better known as the Johnson RING-Snap and ROLL-Snap gages and comparators.

Facilities for setting and maintaining gages and comparators will be exhibited. The many accessories which are used in conjunction with standard comparators for checking squareness, concentricity, etc., of related surfaces will be demonstrated.

The application of these gages in the statistical quality control field as well as conventional inspection usage, will be covered. A new manual covering the installation of a complete quality control system for the small screw machine shop will be shown.

Booth 6

WILSON MECHANICAL INSTRUMENT DIV.

The normal "Rockwell" hardness tester and "Rockwell" superficial hardness tester will be shown at Booth 6—exhibited by the Wilson Mechanical Instrument Div., American Chain & Cable Company, Inc. These are the latest models in the "Rockwell" line of hand operated hardness testers and they will be set-up for operation.

The new "Rockwell" motorized hardness tester will also be shown. This is a semi-automatic normal model "Rockwell" hardness tester—wherein the major load is applied under dash-pot control and removed by motor. This model has the new Set-O-Matic dial gage, which eliminates the necessity of the operator setting the gage to zero.

Wilson engineers will be on hand to demonstrate all "Rockwell" models exhibited. Viewers are sure to find the subject—and s p e e d—of "Rockwell" hardness testing a most interesting one.

So, stop in at Booth 6, and see "Rockwell" hardness testers in testing action.

Booth 18

THE L. S. STARRETT COMPANY

The L. S. Starrett Company of Athol, Mass. will display their complete line of dial indicators and dial gages. These are manufactured to meet the highest standards of precision performance for all quality control gaging and inspection operations.

Starrett's exhibit will also include many other items that go hand in hand with many quality control programs such as micrometers of all types, height gages, vernier calipers, gear tooth vernier calipers, depth gages and other precision hand measuring tools.

In attendance at Starrett Booth No. 18 will be Mr. W. W. Haskins, Western Sales Manager; Mr. L. E. Gibson, Factory Representative in the St. Louis area; Mr. R. E. Brackett, Dial Gage Sales Engineer and Mr. H. V. Blakley, Experimental Engineer from the Company's home office and factory at Athol.

Booths 21-22

OPTICAL GAGING PRODUCTS, INC.

Directed toward cost reduction in industrial production, Optical Gaging Products, Inc. presents a working exhibit of the advantages of optical projection gaging on the production line and in the toolroom.

Featured is a new method of gear analysis by which all elements of gear tooth construction may be inspected

and gaged visually, making possible group discussions of gear element discrepancies, and aiding production quality control. It permits complete analysis of gears, without need for master gears or interpolative data.

A fast new method of inspecting production parts by comparing shadows of a sample part and master part *simultaneously* will be demonstrated. Another universal type of gage for rapid inspection of shafts and similar screw-machine parts further demonstrates the cost-saving versatility of optical projection gaging.

Close tolerance inspection by use of the MICRO-GAGE principles of comparator chart making can be discussed and tested by booth visitors. Optical gaging representatives are prepared to explain the use of materials and methods for making comparator charts and fixtures in the user's plant.

Booth 23

RIMAT TOOL COMPANY

Portable internal comparators will be featured by RIMAT Tool Company of Pasadena, Calif. in Booth 23. These versatile instruments will be of particular interest to show visitors concerned with dimensional control of inside diameters. RIMAT'S display will include representative gages for checking diameters of internal "O"-ring grooves and snap-ring grooves; diameters of internal thread reliefs and stepped counterbores; and pitch diameters of internal threads. Inside micrometers and gages for measuring location and width of internal recesses will also be shown.

Company personnel will be on hand to explain the universal application of these instruments to routine inspection and quality control procedures. Show visitors seeking a specific solution to particular internal gaging problems are cordially invited to bring them to Booth 23. "If you can machine it inside, RIMAT can measure it."

Booths 24-25

FEDERAL PRODUCTS CORPORATION

New gages in the Federal line which will be exhibited at the ASQC Convention include the latest instrument for measuring shallow diameters, a universal ID-OD gage known as Model 88P-10. Other new developments among the dial indicator gages are on "O"-ring gage, a crankshaft gage, and a gear gage. New advances in air gaging that will be shown are Federal's Airprobe, a universal contact unit that operates in conjunction with the Federal Dimensionair. Also new is the Arnoldair attachment which is used in combination with the Arnold grinding gage and the Dimensionair to eliminate pointer flutter and enable the grinder operator to grind down to size with confidence.

Of course, all of the well-known Federal indicating gages, which are so essential to statistical quality control, can also be seen at the Federal booth. Other gages on exhibition will include the Electricator, which is an electrified dial indicator, and the various electronic measuring devices produced by Federal.

C. W. (Cliff) Kennedy, well-known quality control engineer, will head up the Federal personnel who will be on hand to explain the various gages and how they can best be applied to quality control. Messrs. B. C. MacDonald, O. L. Scott, R. Henning, and J. W. Kelly of the B. C. MacDonald Company, Federal's St. Louis representative, will also be in attendance.

Booths 27-28

MONROE CALCULATING MACHINE CO.

Effortless statistical computation will be shown on the modern Monroe calculator. "Quality Control" and "Statistical Methods," two of Monroe's highly accepted literary aids, will be available on request. Ask a Monroe representative to demonstrate chi square, skewness, kurtosis or regression on the Monroe fully automatic calculator.

The Monroe statistical calculator and Monroe dual register adding machine—the perfect quality control computing team—will be the keynote of the exhibit. Monroe's statistical calculator offers an improved automatic squaring lock, a Veeder counter for registering the number of items squared and special upper dials which show individual as well as accumulated values. The Monroe dual register adding machine aids statistical calculations by recording data in a convenient, rapid and accurate manner.

Monroe machines and service are available in all leading cities.

Booth 31

ELLIOTT SERVICE COMPANY

Featured at the Elliott Service Company's display will be the following management services:

1. Colorful "Quality-Cost" Displays for weekly departmental posting in large and small manufacturing plants to help stimulate employee quality consciousness.
2. A complete bulletin board display service to reinforce management's daily contact with employees. This display features colorful, weekly poster presentations of those subjects requiring plant-wide cooperation, such as quality workmanship, waste and cost reduction and accident prevention. Special posters are available for the textile industry. Bulletin display boards are furnished in silver-gray, hammered-tone, or green baked-enamel finish.
3. Samples of "MANAGEMENT INFORMATION for Foremen and Supervisors," a weekly bulletin covering quality maintenance, waste and cost reduction, human relations, supervisor's personnel functions, training, safety. Also samples of supervisory training outlines and booklets on similar subjects.
4. Elliott Suggestion System Service samples, including weekly THINK-Stimulator displays, suggestion panel boxes and monthly Suggestion Bulletins.

Booth 33

INDUSTRIAL SCIENTIFIC COMPANY

Industrial Scientific Company makes the PROBOGRAPH, an instrument for checking and measuring machine parts: gears, cams, turbine blades, propellers.

The PROBOGRAPH operates practically automatically by means of an electric probe. Each measurement is recorded as a graph on a chart ready for quality control use. Precision, reliability, and clarity are characteristics of the PROBOGRAPH. It is an instrument both for gageroom use and mass inspection.

Three universal models and many single purpose instruments are available. One of each type will be exhibited.

The man who has pioneered PROBOGRAPH and made it one of the most advanced measuring techniques will be on hand showing the latest methods of gear checking, cam checking, inspection of blades, etc. There are many precision parts which probably only the PROBOGRAPH can inspect successfully.

Many years of practical experience have made the PROBOGRAPH system the last word in precision inspection and quality control technique.

Booth 34

FRIDEN CALCULATING MACHINE COMPANY, INC.

The Friden fully-automatic square root calculator will be exhibited and demonstrated on quality control problems, including correlation, analysis of variance, moving averages, standard deviation, correlation coefficient, cube root and fully-automatic square root.

The Friden is the world's first and only desk calculator with automatic square root. It provides fully automatic extraction of square foot plus all the other time-saving advantages which enable the Friden to do more kinds of figure work without operator decisions than any other calculating machine ever developed.

To extract the square root, the operator merely sets the number on the keyboard, and touches the small key corresponding to the decimal point in the number. The square root appears

(Continued on page 38)

The Old Fashioned Plug Is Out Moded

In This Fast-Rolling MODERN Age

Users everywhere say:

DuBo* is the MODERN Plug Gage

*U.S. and Foreign Patents Granted

Gaging Surfaces are Portions of a Sphere

Operates by Tilting Handle

Whether handle will drop freely or not is the definite yes-or-no indication. No guesswork, no forcing, no fumbling!

COLOR Gives INSTANTANEOUS "FOOL-PROOF" INDICATION of GO and NO GO

For Quality Control

NO plug gage can equal DuBo

. . . IN ACCURACY

. . . IN EASE OF HANDLING

. . . IN SENSITIVITY

. . . IN LIGHT WEIGHT

. . . IN LONG TERM SERVICE

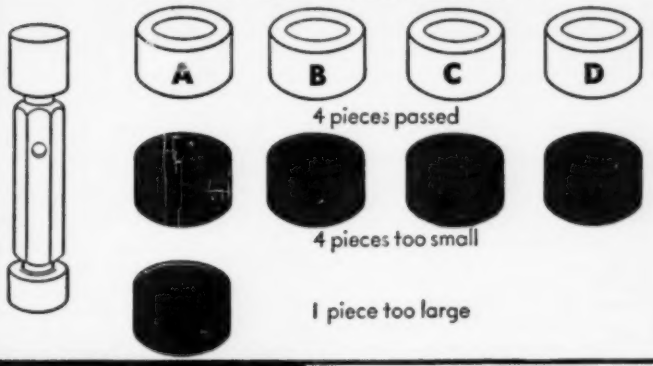
. . . IN COST SAVING AND PROFIT

Like so many items of modern design, DuBo Plug Gage *looks* different and *feels* different from the conventional plug gage. And even craftsmen of the old school, used to time-worn methods, quickly get the feel and take pride in the use of this *different* tool. *Added to that are the many actual cases where DuBo, after a fair trial, has replaced conventional plug gages.*

With exceptional ease of handling, DuBo gives a precise, definite and sensitive check of bore diameters, directly and with no element of confusion, even in unskilled hands. In the same application, DuBo reveals dimensional variations such as taper and out-of-round which ordinary plug gages cannot indicate.

An ABC Demonstration of DuBo* Plug Gage Superiority

Inspection of 9 pieces using conventional plug gage
Bore Diam. 1.500"; Total Tolerance .001"



RESULTS of same inspection using DuBo Plug Gage

Of the 4 pieces passed by conventional plug gage above, only 3 are actually within specified limits when inspected with the more sensitive DuBo plug gage.

DuBo reveals piece D (passed above) is too large.

Of the 4 rejected as too small by conventional plug gage, E and F are actually within the limit when inspected with DuBo plug gage.

I, rejected by conventional gage as too large, is so verified when inspected with DuBo plug gage.

Of nine pieces inspected, DuBo reclaimed two false rejects and rejected one piece that had been passed by ordinary plug gage inspection. Apply even a fraction of this ratio to a day's production in your own plant and you'll realize the advantage of using DuBo Plug Gages.

COST-SAVING FACTORS

DuBo Plug Gages outlast ordinary plugs many times. Extremely light in weight (in the larger sizes, 70% to 80% lighter than cylindrical plug gages of equivalent diameter) and requiring no jockeying into position for entry, DuBo effects economies in that important cost item, actual inspection time.

Use DuBo for Precision Plug Economy

When inspecting parts under quality control sampling procedure, it is important that those parts which may be close to either end of the tolerance range be properly classified. The definiteness and simplicity of DuBo gaging is a decided advantage in this type of inspection. Anyone who has tried to enter a cylindrical plug into a hole only .0001" larger than the gage, knows how difficult it is. For even skillful workers there is a point at which it becomes doubtful whether the bore is actually smaller than the gage size, or if it is larger and merely close. With DuBo Plug Gage, even an unskilled worker can easily enter the gage under any condition and quickly interpret bore conditions correctly. There need be no border-line cases of doubt regarding the proper classification of a bore. Use of the DuBo Plug Gage minimizes the cost of parts needlessly rejected and the expense accruing from those incorrectly passed.

TRY DuBo! Sense its craftsmanlike feel and balance. See how easily it enters, even in undersize bores . . . how gentle manipulation of the handle accurately reveals internal conditions. Use it on a *fussy* job and you'll KNOW why DuBo is replacing old time plug gages everywhere! Refer to Catalog C, Pages 18, 19, 20, 21. Or, write or phone for more detailed information.

STANDARD Gage Co., Inc.
POUGHKEEPSIE, N.Y.

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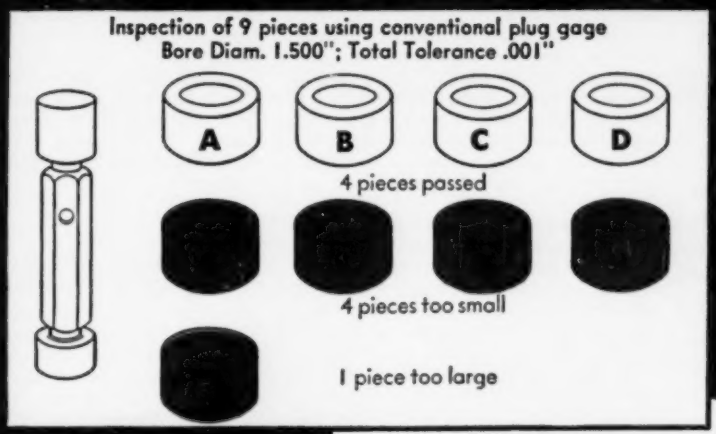

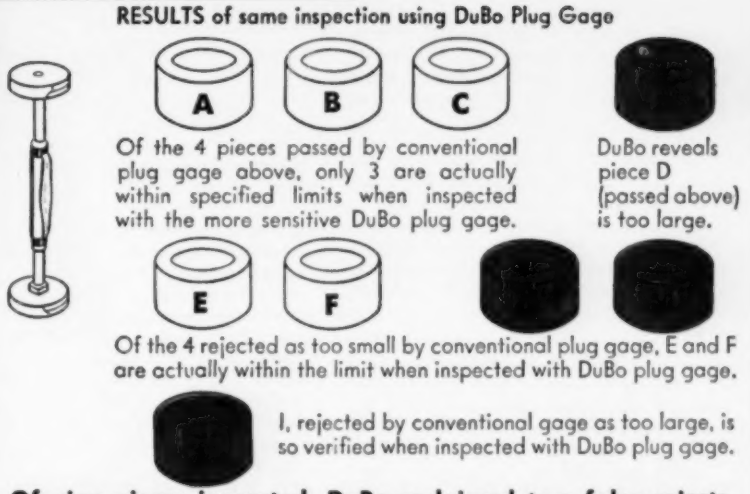
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STANDARD Gage Co., Inc.
POUGHKEEPSIE, N.Y.

m the dials almost instantaneously. If desired, the root is retained in the machine for further calculation, eliminating the need for copying the root to the keyboard, with consequent chances for error.

Booth 36

STEEL CITY TESTING MACHINES, INC.

Feature attraction in Booth 36, Steel City Testing Machines, Inc., will be the new Flex-Tester for testing sheet metal to determine its drawing qualities and stretcher strain characteristics. Developed by Jones & Laughlin Steel Corp., this revolutionary device has enjoyed tremendous success all over the world during its first year. Quality control personnel in many of the country's leading stamping plants have found the Flex-Tester a most valuable tool. See it in operation!

The Steel City display will include other types of equipment for testing the physical properties of metals. Brinell hardness testers will be represented by a laboratory model and a portable instrument. A hydraulic ductility testing machine (cup test) will be in operation. One of the Company's direct-reading type proving rings will also be exhibited, along with miscellaneous accessories. Steel City also manufactures tensile, compression, hydrostatic, transverse and special testing machines.

Booth 37

BROWN & SHARPE

Brown & Sharpe will display electronic production measuring and inspecting equipment for taking measurements electronically in units from 0.0001 to 0.00001 in. Included will be a comparatively new item, electronic caliper gage, for high precision gaging of work on the bench or in the fixture or machine.

Representative Johansson gage blocks and accessories will be shown with a complete line of precision tools and the new Brown & Sharpe micrometers, the only micrometers in America with a one-piece stainless steel spindle and screw. The Intrimik, a new internal tri-point micrometer, is of especial interest in sizes for the precision measurement of bores and holes from 0.275 to 8.000 in.

Permanent magnet chucks and other items from the line of Brown & Sharpe precision products used in the maintenance of quality control will be on exhibit.

James Casagrandi and William J. Hessels of the Brown & Sharpe sales organization plan to be on hand to greet visitors.

Booth 39

CENTURY ELECTRIC COMPANY

Century Electric will exhibit their products showing a step-by-step method of quality control techniques which are used in the various stages of manufacturing motors.

Component parts of various motors will be exhibited together with the gages and quality control charts which relate to the specific component. A cutaway view of a Century Form F fractional horsepower motor will be exhibited. Quality control methods used in the manufacturing will be explained.

In addition to the exhibit the Century Electric Company is also offering a plant tour for all delegates to this convention. Century plants are located at 1806 Pine Street just four blocks from the auditorium where the exhibition will be held.

Mr. Frances Fisher, Chief of the Inspection and Quality Control Division, will be in charge of the exhibition.

Booths 40-41-42

BRYANT CHUCKING GRINDER COMPANY

A line of internal and external thread gages, both portable and bench type, are to be shown by Bryant Chucking Grinder Co., Springfield, Vt. These gages are built on the principle of an "expanding" master plug for checking internal threads or a "contracting" master ring for checking external threads. Paired segments, one movable, actuate a dial indicator which shows the accumulated amount of variation from basic size. Interchangeable segments cover a range of thread sizes up to 5 in. in all tolerance classes. An attachment for checking squareness of face with the thread will be demonstrated on both internal and external bench gages.

A new line of granite surface plates made from famous Rock of Ages granite will be exhibited. Standard sizes of these plates range from 12 x 18 in. up to 36 x 48 in. and the overall accuracy is guaranteed to 0.0001 in the smaller sizes or 0.0002 in the larger sizes.

Booth 43

BRUSH ELECTRONICS CO.

Brush will feature the Surfindicator, Uniformity Analyzer and Tension Analyzer.

The Surfindicator is a practical shop instrument for measuring surface roughness simply but accurately. Accessories to the Surfindicator include the motor drive and the small bore pickup. The motor drive provides mechanical movement of the Surfindicator pickup along a surface being inspected. The small bore pickup provides additional flexibility for measuring small inside diameters of machined surfaces.

The Uniformity Analyzer is a textile instrument which measures the irregularities in weight per unit length of yarn, roving and sliver.

The Tension Analyzer is a new instrument which measures the variations in tension, from 4 grams up to approximately 200 grams in any filament yarn or wire. It records these variations permanently on a chart.

In attendance at this show will be: D. C. Lynch, A. J. W. Novak, L. L. Anderson, W. R. Stern, F. W. Witzke, A. Ondis, T. Thompson, D. Gaskill, A J. Walcutt.

Booth 46

MICROMETRICAL MANUFACTURING CO.

Profilometer — Micrometrical Manufacturing Company announces the new Profilometer Type QA Amplifier for shop measurement of surface roughness. This unit is used with all Profilometer Tracers, old or new, and shows the average height of the roughness irregularities in microinches (millionths of an inch) as the tracer is moved along the work. The readings are either arithmetical or r. m. s. average as selected by a switch on the panel.

This Amplifier, like all Profilometer equipment, is designed and built for use in production departments. The Amplimeter conforms to the proposed new ASA Standard B46.1 as regards all technical details. This new unit is designed for use with all Profilometer equipment developed since 1936.

Plan now to attend the ASQC Convention, St. Louis, Missouri, June 9, 10 and 11, 1954. All Profilometer equipment will be on display in Kiel Auditorium, Booth 46. Our representatives will be on hand to answer your questions and to demonstrate our equipment.

Booths 48-49

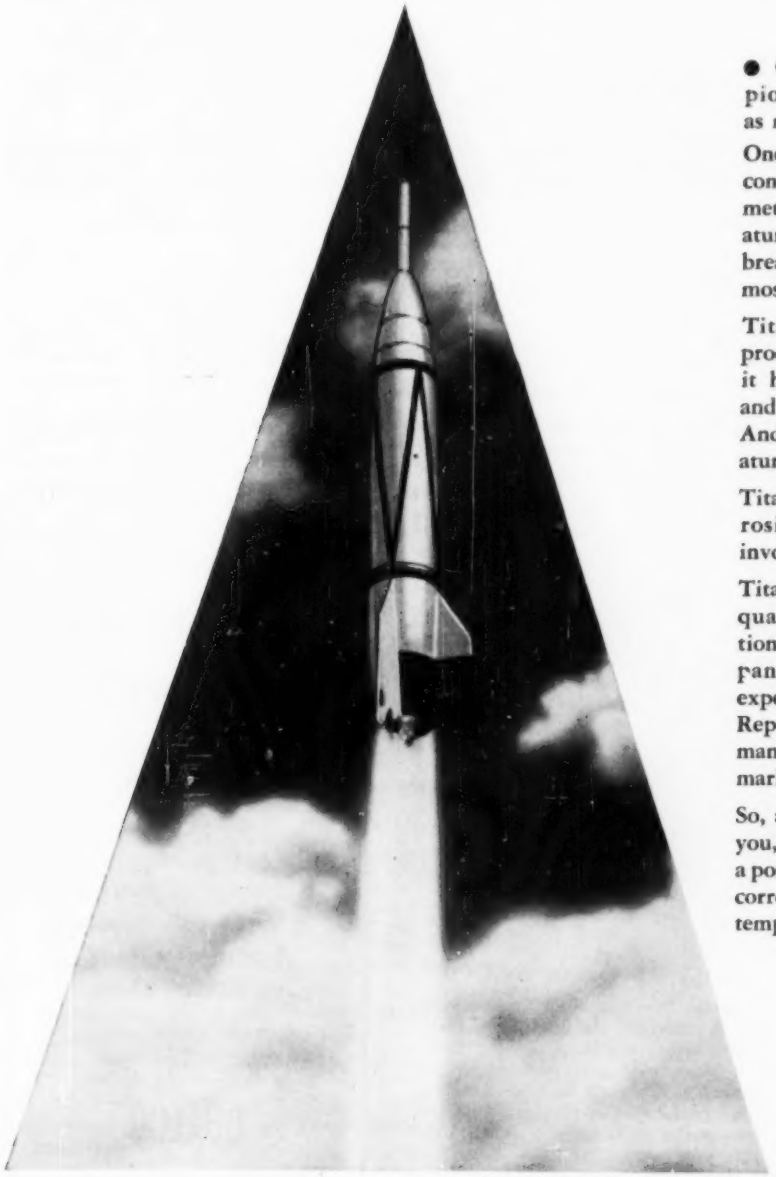
THE TAFT-PEIRCE MANUFACTURING COMPANY

The Taft-Peirce exhibit will place major emphasis upon the many uses of CompAIRator air gages in inspection operations. In addition to standard air plugs, air rings, and air snap gages, examples of small hole gaging and wide tolerance gaging will be shown. The CompAIRator readily checks diameters as small at 0.055 in.; at the other extreme, air-contact gaging permits measurement of tolerances up to 0.120 in. An air-electric CompAIRator, which gives simultaneous signal light and dial indications, will also be on display.

A special feature of the air gage exhibit will be the Taft-Peirce Computing CompAIRator, an unusual gage that actually computes difficult measurements automatically. This type of unit eliminates the need for two measurements and a calculation, and has many applications in industry.

To round out its display of quality control tools, Taft-Peirce will also show its precision gage blocks, fixed gages of

MISSILES HELPING TO BREAK A NEW INDUSTRIAL BOTTLENECK



● Guided missiles and rockets are pioneering civilian progress as well as military.

One of the bottlenecks facing many a commercial idea is lack of lightweight metals that can withstand high temperatures. The outstanding candidate for breaking this bottleneck, the metal uppermost in the nation's mind, is titanium.

Titanium is one of the metals being produced for missiles and rockets because it has about half the weight of steel and twice the strength of aluminum. And it can hold its strength at temperatures possibly up to 1000 F.

Titanium promises well also where corrosion is the bottleneck, especially involving brine and chlorine.

Titanium is not yet available in sufficient quantity for many industrial applications. But Repubic Steel and other companies are doing research which is expected to improve this condition. Republic Steel both melts and rolls the many types of titanium metal being marketed by Republic.

So, as soon as titanium is available for you, turn to Republic's experience for a possible solution to ideas which require corrosion resistance or light weight at temperatures not now practicable.

REPUBLIC STEEL

GENERAL OFFICES • CLEVELAND 1, OHIO

REPUBLIC STEEL

WORLD'S WIDEST RANGE OF STANDARD STEELS AND STEEL PRODUCTS

all types, the new granite surface plate, and its "Rotochek" power thread gaging units. Of particular interest is the new bench model Rotochek, especially designed for rapid bench inspection of threaded products.

Booths 53-54

AMERICAN CYSTOSCOPE MAKERS, INC.

American Cystoscope Makers, Inc. extend a cordial invitation to members and guests of the American Society for Quality Control to visit their exhibit in Booths 53 and 54. Borescopes, precision visual inspection telescopes, will be on disply. A new model jointed borescope for pipeline inspection will be shown. Representatives will be present to discuss individual inspection problems.

Booths 55-56

ENGIS EQUIPMENT CO.

Featured at the Engis Equipment Company's booths will be optical and electronic quality control instruments for the following purposes.

Optical tooling units consisting of precision alignment telescopes, autocollimators, sight levels, theodolites, jig transits, with a comprehensive range of accessories. These units determine precisely straight, parallel, square and angular alignment on a large variety of tools, gages, fixtures, machines and components and assemblies.

Their design accommodates a large range of sizes from small precision parts to the largest machine tools. They serve in the set-up and testing of production machinery, the periodic checking of gages, as well as for the precise evaluation of production samples.

The electronic instruments (Talysurf, Talyrond, Talymin III) provide precise numerical average values of surface finish, and permanent records of surface finish, deviations from true roundness, and errors in straightness, screw-lead, gear-performance, etc.

Besides, the display will contain special and standard gaging equipment, including twist drill gages, cylindrical squares, precision engineers' levels and clinometers.

Booths 59-60

SHEFFIELD CORPORATION

Among the new gaging devices for use in quality control to be exhibited by the Sheffield Corporation, Dayton, Ohio, are two kits of adjustable air gaging spindles, one covering a range of 1 to 3 in., the other from 3 to 12 in. Of special interest will be the applications of Plunjet gaging cartridges to gaging fixtures and machine tool control "feed" gages.

New toolroom as well as production gaging instruments will be displayed.

New model Precisionaire Column instruments and new style high amplification Dial Precisionaires will be displayed for the first time before any ASQC group. Newly developed gages for the textile, printing and paper industries are expected to be ready for showing at the Convention.

A complete staff of qualified Sheffield engineers will be at the exhibit as well as representatives from the surrounding area.

Booths 63-64

FORD MOTOR COMPANY

Ford Motor Company in Booths 63-64 will feature the thorough systemization of receiving inspection activity on very large volume in order to gain the most efficient use of available inspection effort. They will demonstrate Ford's approach to this problem as well as the problem of simple interpretation of a great volume of vendor's quality reports and data.

Booths 65-66

MC DONNELL AIRCRAFT CO.

The McDonnell exhibit will consist of a semi-automatic ultrasonic inspection unit which makes use of the submerged scanning techniques. McDonnell has pioneered in the development of this new adaptation of the use of ultrasonic inspection techniques which is in use on a production basis in only a few locations in the country.

The technique provides the only proven method by which internal discontinuities may be discovered, measured and precisely located in die-forgings and forged billets. With the advent of the rapidly increasing size and weight of airflame forgings the problem of securing metallurgically sound items has become magnified. It is difficult for the foundries to produce aluminum alloy forgings, fifty pounds and over in weight, which do not contain voids of some degree of magnitude and frequency.

Booth 68

SERVICE DIAMOND TOOL CO.

Service Diamond Tool Company has greatly enlarged its production facilities to satisfy the large demand for its new Model "A" hardness testing machine for Rockwell testing. The machine performs the standard Rockwell tests, and is made in both standard and superficial series. It has been improved so as to provide more efficient production testing, more accurately standardized testing and rugged dependability by means of the following features:

1. Recessed eye-ease dial, non-glare light focused on work.
2. All controls conveniently grouped, standardized weights, totally enclosed, chrome plated.
3. Unique friction-free spindle unit (pat. pending), ground and lapped elevating screw, hardened, ground and lapped bushing for anvils.
4. Standard movement frictionless bezel dial indicator completely enclosed against dirt and dust. Precision ball bearing beam pivot—no replacement—ever.
5. Enclosed adjustable speed dashpot is easily reached. Linkage and dashpot one compact subassembly.
6. Casting and all moving parts rust and corrosion proofed. Accessory rack enclosed to protect anvils. Telescopic screw sleeves of chrome-plated steel.
7. Generous oversize sections in a one-piece casting, base machined square with elevating screw for stability, less frame deflection than any other machine for Rockwell testing.

A newly developed series of motorized hardness testing machines for either standard or superficial Rockwell testing, will be exhibited. They are the most accurate production testing machines ever made, and feature complete shutoff or motorized components during the actual hardness testing penetration. This eliminates the largest source of error in previous motorized equipment for Rockwell testing .

WHAT ARE YOUR TEST EQUIPMENT PROBLEMS?

•

Designers and Manufacturers of Destructive and Non-Destructive Testing and Measuring Equipment.

•

QUALCO

102 WINDERMERE DRIVE
YONKERS 4, N. Y.

A. A. Speranza, Jr. Telephone
Member of ASQC. SPencer 9-3139W

NEW

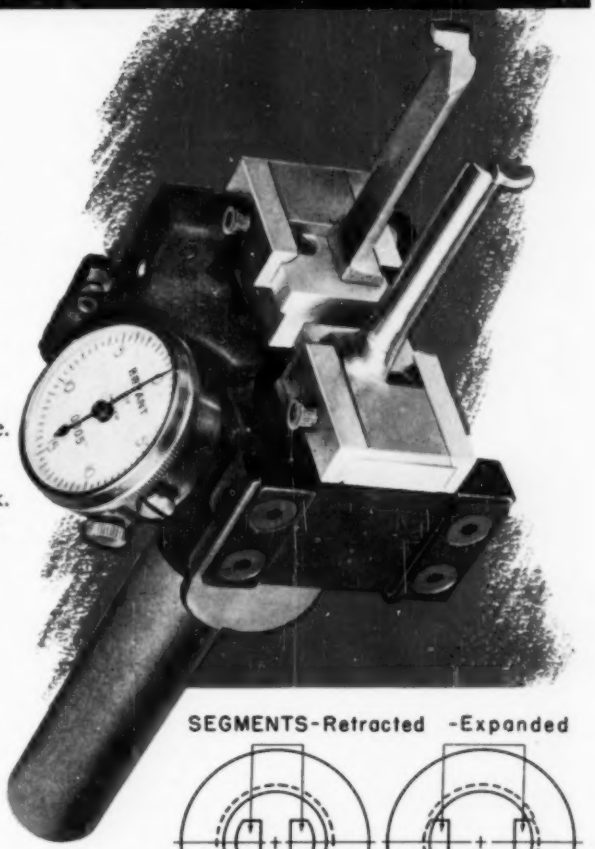
BRYANT PORTABLE GROOVE GAGE

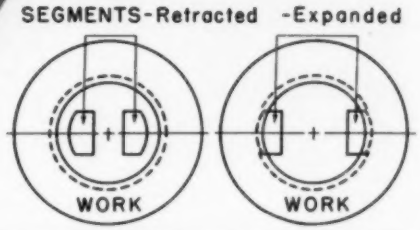
an extremely fast, accurate gage for statistical quality control!

Bryant proudly introduces the latest development of Bryant research — a new, portable groove gage that offers a truly accurate means of checking the diameter and roundness of internal grooves.

This adjustable gage covers a range of groove diameters up to 5″, and will check grooves which are located to a depth up to 1″ or 2″ from a face, depending on the diameter of the groove.

Actual checking of the groove is done by a pair of segments mounted on platforms, one of which is movable. A thumb lever collapses the movable, spring loaded segment so that the gaging members may enter the work. Release of the lever permits the segment caps to expand into the groove. The movable segment actuates a precision dial indicator which shows variation from basic size. An indication of groove roundness is obtained by rotating the work part on the segments, or by rotating the gage in the work.





OTHER IMPORTANT FEATURES:—

- Four pairs of segments cover standard "O" ring grooves from 1/16″ to 4 3/8″ dia.
- Four pairs of segments cover standard snap ring grooves from 1/4″ to 5 1/4″ dia.
- A single pair of segments may be adjusted over a two inch range, making them applicable to many non-standard grooves.
- Gage gives direct reading of variation of groove diameter from basic size.
- Gage has no slides or pivots.
- Weighs only 18 ounces.

BRYANT CHUCKING GRINDER COMPANY, Springfield, Vermont, U.S.A.

Internal Grinders • Internal & External Thread Gages
Granite Surface Plates • Boring Machines

Send coupon today for free descriptive literature

Bryant Chucking Grinder Co. 10C
Springfield, Vermont

Gentlemen: Please send information on the new Bryant Groove Gage.

NAME.....

TITLE.....

COMPANY.....

STREET.....

CITY.....ZONE.....STATE.....

How to Cut the Cost of Gaging Threads

with TAFT-PEIRCE JOB-RATED GAGES

The *best* gage for most jobs provides the *best* combination of speed, wear-resistance, upkeep, and initial cost. Here are some comparisons that will help you keep costs to a minimum.

Thread Plugs

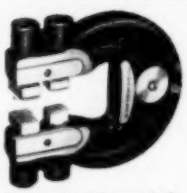
T-P Limit Thread Plug Gage. Standard hardened steel gages are lowest in initial cost and are preferable when soft or moderately hard materials are being inspected in limited quantities. Taper-Lock up to 1.510". Reversible from #0 to ½". Reversible Tri-Lock above 1.510".

T-P Electrolized Gages. With only a modest increase in initial cost, substantially longer wear life can be obtained with this exclusive surface treatment. Many users report up to 3 times longer gage life.

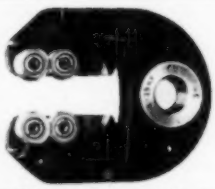
T-P Carbide Thread Plug Gage. For exceptional resistance to abrasion or scratching and maximum wear life. Furnished in both standard and special sizes — from #8 machine screw size up.

Rings & Snaps

T-P Thread Ring Gages. Lower in initial cost than other gages for external threads, they check a combination of all thread errors but cannot distinguish between them.



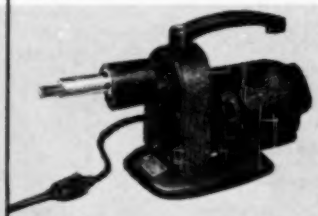
T-P Adjustable Thread Snaps. Faster than ring gaging, and just as accurate, they check lead, angle, and all other thread elements. Pitch diameter is variable.



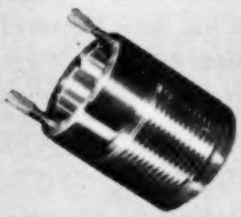
T-P Roll Thread Snaps. Same as adjustable, with *rolls* for gaging members. Since gaging members rotate, wear is spread over greater surface and service life increased.

Special Gages

T-P Rotochek (Flexible Shaft Model). Fastest thread gaging method yet devised. Push —and the gage screws into the work. Release the pressure and it stops. Pull—and it disengages. Can be used with most standard T-P plug or ring gages.

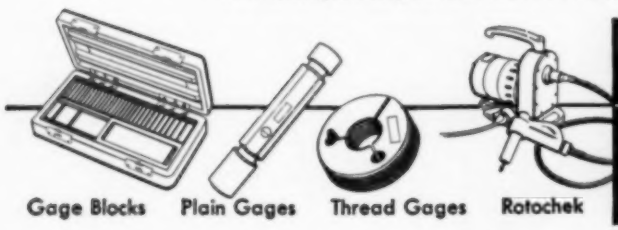


T-P Rotochek (Bench Model). Permits bringing work to gage, instead of gage to work. Like flexible shaft model, records indicate it triples rate of parts inspection.



T-P Thread Concentricity Gage. Typical of the infinite variety of special gages made to order by T-P every year. This one checks size and location of internal threads.

For the complete story on these items and many more, send for your copy of the Taft-Peirce Handbook.



Gage Blocks Plain Gages Thread Gages Rotochek

T-P means Top Precision

T P

THE TAFT-PEIRCE MANUFACTURING COMPANY, WOONSOCKET, R. I.

Before You Buy any Air-Gage

you should know these 4 facts about a T-P CompAIRator

1. It's Faster! There's no flutter nor falling off of the pointer. No guesswork required. Readings are virtually instantaneous *even when long extension hoses are used.*

2. More Versatile! No other air gage matches the instant accuracy of this velocity-type circuit for such a wide variety of applications — from simple internal diameters to simultaneous checks of concentricities, squareness, center distance, etc. — bellmouth or barrel shapes.

3. It Costs Less to Operate! Vibration, hard knocks, jarring — even tilting — do not disturb the accuracy of a T-P CompAIRator. Its rugged construction eliminates expensive maintenance.

4. It Has A Wider Range! A T-P CompAIRator can be simply, quickly applied to check any dimensional relationship — even down to internal diameters as small as .055″ . . . tolerances from .0001″ to .120″. No other air gage approaches this range. It means wider application, greater usefulness, more gaging for your money.

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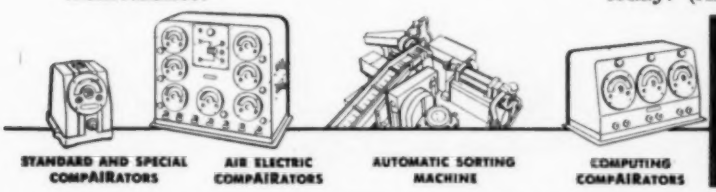

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J. M. JURAN, *Editor*

Correspondence is invited on potential contributions or problems appropriate for discussion in this department. Address your suggestions to:

J. M. Juran
195 Beech Street
Tuckahoe, N. Y.

DEFINITIONS

During the last year this department has taken on a number of assignments to "moderate" panel discussions on quality control. A by-product of these discussions has been a set of proposed definitions which might well be useful to many members of ASQC.

These definitions have had their origin in the preliminary meetings of panels, prior to holding the discussion before the audience.

That discussion is, of course, unrehearsed. However, it is necessary at the preliminary meeting to agree on what is the meaning of basic terminology. Unless there is such an agreement, the audience (or any other panel member) cannot understand what a panel member is talking about when he uses the very words around which the discussion is to be held.

In the last four panels conducted, agreement was reached on the following definitions:

Control is the totality of all means whereby we establish and achieve a standard of performance.

Quality Control is the totality of all means whereby we establish and achieve a quality specification.*

Statistical Quality Control is that part of the means, for establishing and achieving a quality specification, which requires use of the tools of statistics.†

In all instances, audiences were told, in effect:

"These definitions are merely to disclose what we (the panel) are talking about when we use these terms during the next two hours. Hence, during the next two hours, keep tuned in on us by using these meanings for our words. After the two hours are over, then you can go right back to the lingo you have been using before the panel session."

A surprising number of audience members have told this department, "I have no intention of going back to my former lingo."

*In like manner, Production Control, Cost Control, etc., can be defined, substituting for "standard of performance," the terms "Production Schedule" and "Cost Standard" respectively.

†In like manner, Statistical Job Evaluation, Statistical Time Study, Statistical Inventory Control might be defined, substituting appropriate terms for "Quality Specification."

FUNCTIONS OF QUALITY CONTROL DEPARTMENTS

At a recent seminar,‡ this department, assisted by L. A. Seder, explored, with a dozen industrial executives, the functions actually being carried on by quality control departments. The resulting list of 37 functions was quite a revelation.

A. Functions associated with planning or controlling the work of the inspection department.

1. Definition of essential quality characteristics of the product, or classifying their relative importance.
2. Preparation of inspection methods sheets.
3. Preparation of quality specifications for appearance and other non-measurable quality characteristics; codification of shop practice.
4. Training of inspectors (and operators).
5. Design of gages and test equipment.
6. Maintaining the accuracy of gages and test equipment.
7. Investigation of salvage possibilities for non-acceptable material.
8. Supervision or conduct of laboratory testing services.

B. Functions of relations with customers or vendors

9. Analysis of customer complaints.
10. Analysis of goods returned for quality reasons.
11. Conduct of customer surveys to study reactions to product quality.
12. Liaison with customers' inspectors (usually the military).
13. Proving in new sources of supply.
14. Analysis of rejections made on vendors.

C. Functions of quality planning

15. Appraisal of competitors product.
16. Determination of economic level of quality.
17. Measure of process capability.
18. Preparation of process specifications.
19. Liaison between Product Research and Production.
20. Participation in new product planning committees.
21. Study of materials handling as it affects quality.

D. Functions of defect prevention

22. Planning defect prevention programs.
23. Investigation of causes of chronic defects.
24. Trouble shooting on current production.
25. Stimulating corrective action by other departments.
26. Leadership in campaigns for Quality Mindedness.

E. Functions of Quality Assurance

27. Measure of loss due to defects.
28. Rating the quality of outgoing product.
29. Conduct of quality audits.
30. Measuring the effectiveness of inspection (usually inspector accuracy).
31. Analysis of cost of inspection.
32. Measure of customer satisfaction.
33. Measure of trend of customer complaints and returns.
34. Preparation of executive reports on quality.

F. Miscellaneous functions

35. Study of quality implications of operator incentives.
36. Selection, training and placement of quality control engineers.
37. Consultation service on statistical methods to entire company.

This is a formidable list. (The function of inspection itself was excluded at the very outset.)

Needless to say, in none of the companies represented did the quality control department perform this entire list of duties. However, every function on the list was being performed in one or more of the companies.

‡Held under the auspices of American Management Association.

Bibliography

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On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to:
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9220 Old Bonhomme Road
St. Louis 24, Mo.

APPLICATION—FOOD INDUSTRY

CONTROL TRIMS COSTLY VARIATION LOSSES, E. Dalton White, (Food Engineering—v. 25, n. 3, Mar. 1953, p. 80)

Advantages and savings are realized by applying statistical control to problems of product uniformity at the Brock Candy Co. of Chattanooga, Tenn.

TASTE TESTING AS AN ANALYTICAL METHOD—STATISTICAL TREATMENT OF THE DATA, Kjell Bengtsson, Stockholm Breweries, Stockholm, Sweden (Wallerstein Laboratories Communications—v. 16, n. 54, Sept. 1953, p. 231)

The author describes the sampling techniques used in the taste testing of beer. A detailed presentation is made of the statistical method for analyzing the data obtained. These techniques include:

The Binomial Theorem method
The Chi Square Analysis method

These are applied to:

The Two Sample method
The Multiple Sample method
The Triangular Test method
The Classification of Taste Testing

Tables of probability and of significance of results are given.

APPLICATION—METALLURGICAL INDUSTRY

SOME TOOLS FOR QUALITY CONTROL (IN THE MECHANIZED JOBBING FOUNDRY), Thomas W. Curry, Lynchburg Foundry Co.
(Foundry—v. 81, n. 10, Oct. 1953, p. 110)

A general discussion of factors affecting grey iron castings and their physical control. The need of accurate data on casting defects and their cause designation is stressed.

APPLICATION—TEXTILE INDUSTRY

PLANNING AN EXPERIMENT IN A COTTON SPINNING MILL, Robert E. Peake, (Applied Statistics—v. II, n. 3, Nov. 1953)

There are few published examples of planned experiments conducted in a factory and even fewer on textile mill uses. In this article, Mr. Peake shows a typical example of an application and the method of solving the technical, statistical and practical problems that arise in determining suitable sample sizes and evaluating the various types of variation encountered in the test results. The particular illustration deals with the evaluation of end breakage obtained with a modified flyer on a roving frame, but the principles are widely applicable in most types of textile mill experimentation.

APPLICATION—METAL WORKING

CONTROLLING VISUAL CHARACTERISTICS ON PRECISION PARTS, Aldis S. Hayes (Tooling and Production—v. XIX, n. 8, Nov. 1953, p. 94)

This article describes some of the problems inherent in the visual inspection of machine parts. The importance of clearly defined objective standards is stressed. The effect of the human element is also considered in detail.

APPLICATION—MISCELLANEOUS

APPLICATION OF STATISTICAL QUALITY CONTROL IN

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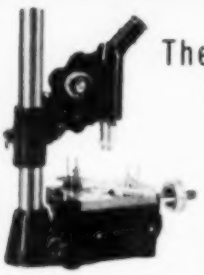

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Quality Control **INSTRUMENTS**

GLASS FABRICATION, T. R. Meyer, J. H. Zambone and F. L. Curcio, Kimble Glass Co., New Jersey
(The Glass Industry—v. 34, n. 10, Oct. 1953, p. 539)

An outline of statistical quality control at the Kimble Glass Co. Part I, covers general application; Part II reviews the development of application; and Part III describes some special techniques used in glass fabrication.

QUALITY PRODUCTION,
(Production—v. 33, n. 1, Jan. 1954, p. 121)

This article outlines very briefly the gaging and quality control techniques used at the Chrysler Indianapolis Plant producing Power Flight Transmissions. (A Quality Control Section is contained as a regular feature of *PRODUCTION.*)

A STATISTICAL QUALITY CONTROL APPROACH TO THE CONTROL OF PLATING SOLUTIONS, Allan D. Woodell
(Metal Finishing—v. 51, n. 12, Dec. 1953, p. 54)

The author outlines some of the necessary functions important to statistical quality control. These are inspection, analysis, and action. These are illustrated with cases in point. Control charts indicating applications to the plating industry are shown.

QUALITY CONTROL IS KEY TO GEAR MANUFACTURE AT HARVESTER'S TRACTOR WORKS, Peter H. Slager, International Harvester Co., Chicago, Ill.
(Machine and Tool Blue Book—v. 49, n. 12, Dec. 1953, p. 168)

Detailed outline of the production and quality control steps in gear manufacturing. Not statistical quality control.

CONTROL CHARTS

A TECHNIQUE FOR STANDARDIZING MASSED BATTERIES OF CONTROL CHARTS, Stafford Beer
(Applied Statistics—v. II, n. 3, Nov. 1953)

Mr. Beer describes a simple apparatus for presenting a large number (up to 50) of control charts in a compact and comprehensive manner, which simplifies comparisons of variations. Such a mechanism should be especially interesting to textile mills with

the large number of variables to be controlled from raw materials through finished product.

CORRELATION

FIELD TESTING AND CORRELATION OF LABORATORY AND FIELD TEST DATA, Louis I. Weiner and Stephen J. Kennedy
(Journal Textile Institute—v. 44, Aug. 1953, p. 433)

The U. S. Quartermaster Laboratories have developed working correlations to predict performance of textile materials. Experimental design, selection of test subjects, and other factors considered are discussed. Examples of correlations are given.

ENGINEERING AND EXPERIMENTS

AN ELEMENTARY INTRODUCTION TO STATISTICS—UNITS FOR MEASURING VARIATIONS IN MEASUREMENTS, W. J. Youden, Statistical Engineering Laboratory, National Bureau of Standards
(Metal Progress—v. 64, n. 3, Sept. 1953, p. 91)

This article introduces measures of variations as mathematical tools of use to the engineer. The average deviation and standard deviation are described in some detail. The F Ratio for measuring significance of observed differences in variables is also described. Some limited discussion of the economics of sampling. Tables of chi square, F Ratio, T Ratio, and others for measuring significance of differences are given.

DOES AN AVERAGE TELL ENOUGH? Alexander G. C. Pilavachi
(Modern Textiles—v. 34, n. 6, June 1953, p. 67)

The average is limited due to its failure to indicate variation among the individual figures. The coefficient of variation is presented as a way of measuring this variation among figures. This is the first article in a series.

WHAT'S IN A SAMPLE? Alexander G. C. Pilavachi
(Modern Textiles—v. 34, n. 7, July 1953, p. 54)

A sample should be the right size to give the information desired to the degree of accuracy wanted. A formula for sample size for a given percentage accuracy

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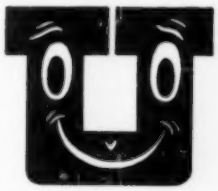

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and cofficient of variation is given. Second article in a series.

DIFFERENCE BETWEEN AVERAGES — TRUE OR FALSE? Alexander G. C. Pilavachi (Modern Textiles—v. 34, n. 9, Sept. 1953, p. 90)

This third article in the series by Mr. Pilavachi discusses the significance of averages of samples. Calculation for significance tests for one mean and for two means are given.

CHECKING ON REGULARITY TESTS, Alexander G. C. Pilavachi (Modern Textiles — v. 34, n. 10, Oct. 1953, p. 70)

The last of Mr. Pilavachi's series discusses significance tests for standard deviations. The F test is illustrated and a table of F values given.

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MANAGEMENT AND PERSONNEL, GENERAL

QUALITY CONTROL IN THE U. S. A., Edward D. Van Rest (Applied Statistics—v. II, n. 3, November 1953, p. 141)

A survey of quality control practice in the U. S. It is noted particularly that quality control is usually regarded in Great Britain as a statistical subject, but . . . . in the U. S. as a branch of management concerned with the control of quality, and control involving not only manufacture to a specification but also satisfaction of the consumer's needs. The following aspects are considered: Scope, Organization, Administration of Quality Control Department, Statistical Techniques, Inspection Specifications, and Teaching.

THEORY AND APPLICATION—GENERAL

QUALITY CONTROL THROUGH STATISTICAL METHODS: III. WHAT IS WRONG WITH MAXIMUM VARIATION?; Norbert Lloyd Enrick (Modern Textiles — v. 24, n. 12, Dec. 1953, p. 79)

Mr. Enrick continues his discussion of variation in this third article of the series. The maximum variation, a maximum range, is discussed and compared to the coefficient of variation. Variation considerations are presented. These cover:

a) Within-Delivery variation
b) Within-Machine variation
c) Between-Machine variation
d) Overall variation

QUALITY CONTROL THROUGH STATISTICAL METHODS: IV. PROCESS ANALYSIS Norbert Lloyd Enrick (Modern Textiles—v. 35, n. 1, Jan. 1954, p. 49)

A detailed discussion of the analysis of process variation illustrated by examples in a textile mill. An "Action Chart" outline for analysis of variance is given. Criteria for action is expressed in coefficients of variation which are discussed in earlier articles in the series.

STATISTICS

SAMPLING DESIGN USED BY THE MINISTRY OF EDUCATION, G. F. Peaker (Royal Stat. Soc., Journal—A, v. 116, pt. 2, 1953, p. 140)

ESTIMATION AND COMPARISON OF STRENGTHS OF ASSOCIATION IN CONTINGENCY TABLES, A. Stuart
(Biometrika—v. 40, June 1953, p. 105)

METHOD FOR JUDGING ALL CONTRASTS IN ANALYSIS OF VARIANCE, H. Scheffé
(Biometrika—v. 40, June 1953, p. 87)

SEQUENTIAL TEST FOR RANDOMNESS, P. G. Moore
(Biometrika—v. 40, June 1953, p. 111)

NON-NORMALITY IN TWO-SAMPLE T-TESTS, D. G. C. Gronow
(Biometrika—v. 40, June 1953, p. 222)

APPROXIMATE CONFIDENCE INTERVALS, M. S. Bartlett
(Biometrika—v. 40, June 1953, p. 12)

EXPERIENCES OF CORRELATION ANALYSIS, D. G. Beech
(Applied Statistics — v. 2, June 1953, p. 73)

ECONOMICS OF SEQUENTIAL SAMPLING PROCEDURES FOR DEFECTIVES, D. G. Champernowne
(Applied Statistics — v. 2, June 1953, p. 118)

ORIGIN AND DEVELOPMENT OF FACTOR ANALYSIS, D. F. Vincent
(Applied Statistics — v. 2, June 1953, p. 107)

CHAIN BLOCK DESIGN, W. J. Youden and W. S. Connor
(Biometrics—v. 9, June 1953, p. 127)

DESIGN AND ANALYSIS OF TRIANGULAR SINGLY LINKED BLOCKS, K. R. Nair
(Biometrics—v. 9, June 1953, p. 141)

OPERATIONS RESEARCH

OPERATIONS RESEARCH, Morley G. Meldon
(Factory Man. and Maint.—v. 111, n. 10, Oct. 1953, p. 113)

In this article the author defines many of the terms used in operations research techniques. The definitions include the kind of problems solved by the various techniques and the statistical methods employed.

OPERATIONS RESEARCH—NEW TOOL OF INDUSTRIAL SCIENCE, Russell L. Ackoff, Case Institute of Technology, Cleveland
(Industrial Laboratories—v. 4, N. 11, Nov. 1953, p. 64)

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Operations research is described as a technique applicable to industrial problems and situations. Problems and models are described in industrial situations. Diagrams illustrate operation research approaches to specific industrial problems.

SAMPLING METHODS IN RAILROAD ACCOUNTING, W. R. Van Voorhis

METHODS OF REDUCING SAMPLE SIZE IN MONTE CARLO COMPUTATIONS, H. Kahn and A. W. Marshall

STATE PROBABILITIES IN CONGESTION PROBLEMS CHARACTERIZED BY CONSTANT HOLDING TIMES, John L. Everett

COMBAT PROBLEMS, WEAPON SYSTEMS AND THE THEORY OF ALLOCATION, Alvin Karchere and Frances P. Hoeber.

(Journal of the Operations Research Society of America—v. 1, n. 5, Nov. 1953)

In addition to the above articles, this Journal contains a table of contents for the five issues in Volume 1. This covers the November 1952, February 1953, May 1953, August 1953 and the November 1953 issues.

REPORTED—NOT REVIEWED

CONCLUSIONS FROM AN OBSERVED PROPORTION, F. Proschan

(Sylvania Technologist—v. 6, July 1953, p. 57)

Problems Department

PAUL C. CLIFFORD, *Editor*

Problems for solution, and correspondence concerning material, published in this department, should be addressed to:

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39 Norman Rd.
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ON TRUNCATED SAMPLING WITH c = 0

Problem 8, proposed in the May issue, was partially discussed in the November issue. Your editor asked Professor Mosteller of Harvard University to comment on this problem. His remarks seemed to have several new contributions: 1) how to reduce considerably the bias in the intuitive estimate and 2) to give approximately the variance of the intuitive estimate. Professor Mosteller's letter follows:

Dear Paul,

The question you ask arises from time to time, and I have often worried about it. This time I got a little further than usual. As you imply, for this problem the unique unbiased estimate of the percent defective based on inspection of one lot is 100 if the first item is defective, zero otherwise. Most people do not like this because it violates their intuition to estimate the percent defective as zero when they have just observed, say, one out of eight items to be defective.

Let us remember the inspection plan being used. The acceptance number is zero, rejection number one, truncated single sampling, with n=50 non-defectives required to accept the lot. This means that the percent defective expected in the process must be small, otherwise quite a large percentage of lots would be rejected, and either the process would be closed down for improvement or else the inspection plan would be relaxed. Lots with 0.1 percent defective have a 95 percent chance of being passed. So we can suppose that the percentage defective for the process is expected to be about this small. The main point is that the process p is very small. This makes it possible to derive some approximate results.

You suggest that in estimating for the outcomes for a sequence of lots the unbiased estimate might not be so foolish. This is indeed the case. First of all, one has a choice of a large number of unbiased estimates, secondly they do not appear quite as silly as in the case when only one lot is involved. There are so many estimates though, that one can scarcely investigate them all. I did investigate one, and I found that for small p the effective sample size was equal to the number of lots inspected. This seems rather expensive in observations, so I considered the more usual case for the estimate of proportion defective

$$p = \frac{\text{number of defectives}}{\text{total items inspected}}$$

I found this estimate to be only slightly biased for small p's. Indeed the expected value (see note I) is about

$$p\left(1 + \frac{1}{2k - 1.5}\right)$$

where k is the number of lots inspected. This means we could approximately unbias the estimate by dividing it by $[1 + 1/(2k - 1.5)]$.

Furthermore the variance of the estimate is about

$$\frac{p}{(k-1)n}\left(1 - \frac{2k-1}{2k\,(k-1)n}\right)$$

where the second term in parentheses can be neglected unless n and k are both small. You may wonder where q is because the binominal variance is pq, but recall that p is practically zero so q is practically unity. If k is small, dividing the estimate by $[1 + 1/(2k - 1.5)]$ may be a good idea, and then the variance is divided by the square of that quantity. So for large n, but small k, the estimate p and its variance would be roughly

$$p_{est} = \frac{\text{defectives}}{\text{total inspected}\left(1 + \frac{1}{2k - 1.5}\right)}$$

$$\sigma^2_{p_{est}} = \frac{p}{n(k-1)\left(1 + \frac{1}{2k - 1.5}\right)^2}$$

You will notice on comparing this with the binomial form pq/n that the effective sample size is larger than n(k—1) which is a large improvement on an effective

sample size of k mentioned earlier for the unbiased estimate.

So what it all comes to is that the usual estimate is pretty good, and that it can be improved on slightly by dividing by a factor. Remember all of this was for small p. As p gets larger the analysis above gets less and less accurate.

Finally, I tried out this approach on k=100 lots (n=50) with known p=0.01. The ratio of estimate defectives to total items was 0.0111, a correction not worth bothering about. The standard deviation is $\sqrt{p/n(k-1)} = 0.0014$, so we are less than a standard deviation from the true value.

For the example given by you, 2/195 would be the estimate, or one percent (see note II).

Now the trouble with this whole thing is that it assumes the process is under control when the estimate is being made. If it is not, then Cochran's article, "Analysis of Variance for Percentages Based on Unequal Numbers," *J. Am. Stat. Assoc.*, 1943, 38, 287-301, applies. I would think that for the setup implied by this sampling plan the estimate I have described would be appropriate —it corresponds to binomial weighting in Cochran's article. Equal weighting would be more appropriate if we thought there was a great deal of variation from lot to lot—say from zero to 25 percent defective. Equal weighing would give (0 + 0 + 17 + 2.5 + 0)/5 = 4 percent as an estimate for your example. However this estimate is extremely biased and needs dividing by something a little smaller than

$$\ln n + \frac{1}{2n} + 0.577$$

which for n=50 is about 4.50, so we get back an answer just about one percent again.

Best regards,

FREDERICK MOSTELLER

Mathematical Notes

I. The bias in p was approximated by noting that if p were sufficiently small the probability associated with more than one lot being rejected could be neglected. The probability of observing (k—1) accepted lots and one rejected lot with t non-defective items is

$$k\,p\,q^{(k-1)n+t} \qquad t = 0, 1, \ldots n-1$$

and the estimate of p is total defectives/total observed items which for the case of one defective is

$$p_{est} = \frac{1}{1 + t + (k-1)n}$$

so the expected value of p is roughly

$$E(p_{est}) \cong \sum_{t=0}^{n-1} \frac{1}{1 + t + (k-1)n}\, k\,p\,q^{(k-1)n+t}$$

But $q^{(k-1)n+t}$ is nearly one because p is so small, so

$$E(p_{est}) \cong p\,k \sum_{t=0}^{n-1} \frac{1}{1 + t + (k-1)n}$$

$$= p\,k \sum_{y=n(k-1)+1}^{kn} 1/y$$

$$= p\,k \left[\sum_{y=1}^{kn} 1/y \; - \sum_{y=1}^{n(k-1)} 1/y \right]$$

$$= p\,k\,(S_2 - S_1)$$

Now if

$$S_2 \cong \log kn + \gamma + \frac{1}{2\,kn} - \frac{1}{12\,k^2n^2} + \ldots$$

$$S_1 \cong \log (k-1)n + \gamma + \frac{1}{2(k-1)n} - \frac{1}{12(k-1)^2n^2} + \ldots$$

$$S_2 - S_1 \cong \log \frac{k}{k-1} - \frac{1}{2k(k-1)n} + \ldots$$

then

$$E(p_{est}) \cong p\,k \left[-\log \left(1 - \frac{1}{k}\right) - \frac{1}{2k(k-1)n} + \ldots \right]$$

Neglecting the second term in brackets gives

$$E(p_{est}) \cong p \left[-k \log \left(1 - \frac{1}{k}\right) \right]$$

By crude curve fitting it turns out that

$$-k \log \left(1 - \frac{1}{k}\right) \cong 1 + \frac{1}{2k - 1.5}$$

so a good estimate of p would be

$$p_{est} = \frac{\text{defectives}}{\text{total inspected} \left(1 + \dfrac{1}{2k - 1.5}\right)}, \quad k \geq 2$$

If k is large, the correction is negligible. The variance is obtained in the same way, but we have the sum $1/x^2$ instead of $1/x$.

II. 2/195 for five lots = 1.025%

$$1 + \frac{1}{2 \times 5 - 1.5} = 1 + \frac{1}{8.5} = 1.12$$

$$\frac{1.025}{1.12} = 0.915\%$$

Equal weighting gives

$$16.7 + 2.6 = 19.3$$

$$\frac{19.3}{5} = 3.86\%$$

The new bias factor for equal weighting is about 4.50 (not this big) so the adjusted value is

$$\frac{3.86}{4.50} = 0.858\%$$

which is close to the 0.9 percent we got for the adjusted binomial weighting.

Equal weighting for my 100 lots gives

$$\Sigma\, 1/x = 4.0185$$

Therefore the estimate of p is, before adjustment,

$$\frac{4.0185}{100} = 0.0402$$

or four percent. Now the adjustment depends on p but its maximum value, occurring when $p = 0$, is $(\ln n + 1/2n + 0.577)$ which in our example is about 4.50. Therefore the final estimate is

$$\frac{4\%}{4.5} = 0.889\%$$

and this estimate is known to be biased downward.

Can we get a second order adjustment? Yes, replace the correction term $1/(\ln n + 1/2n + 0.577)$ by a new correction term

$$\frac{1 - (p_{est})_o}{\ln n + \frac{1}{2n} + 0.577 - n\,(p_{est})_o}$$

where $(p_{est})_0$ is the first adjusted estimate, and multiply this by total defectives/total items.

The sequence is

Estimate

$$p = \frac{\text{total defectives}}{\text{total items}}$$

Adjusted estimate,

$$(p_{est})_o = \frac{\text{Estimate p}}{\ln n + \frac{1}{2n} + 0.577}$$

Final adjusted estimate

$$p_{est} = \frac{\text{Estimate } [1 - (p_{est})_o]}{\ln n + \frac{1}{2n} + 0.577 - n\,(p_{est})_o}$$

For our example of 100 lots this gives us

Estimate = 4.02%

Adjusted Estimate = 0.889%

Final Adjusted Estimate = 0.985%.

The last adjusted estimate agrees reasonably well with the binomially weighted estimate of 1.1 percent.

Practical Aids

ELLIS R. OTT, *Editor*

Send your "Practical Aid" contribution to:
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New Brunswick, N. J.

SQC's Ugly Duckling

(Use of Tables of the Binomial)

C. J. KIRCHEN

Lincoln-Mercury Div., Ford Motor Co., Detroit, Mich.

INTRODUCTION

The author's candidate for the honor of being the ugly duckling is

$$\frac{n!}{x!(n-x)!}\,p^x(1-p)^{n-x}.$$

This, of course, is none other than than a general mathematical expression for any term of the binomial $[p+(1-p)]^n$, where n is the size of a sample drawn from a lot whose fraction defective is p and whose fraction effective is 1—p, and with the condition that p remains constant as the successive items of the sample are drawn. The expression given above has long been recognized as being directly applicable to statistical quality control where quality is measured in terms of fraction defective. Its "ugly duckling" character stems from the fact that wh le it is simplicity itself to define the tool to be used for such quality control problems, actual use of the tool has been very discouraging because the required calculations are very tedious to make.

AVAILABLE TOOLS

The change from "ugly duckling" to "beautiful swan," in keeping with the Hans Christian Andersen story, has been accomplished through the availability in recent years of tables which provide values of individual terms and of sums of terms.* The author has had access to the National Bureau of Standards Tables, and after some usage of this book, he decided to prepare tables† abbreviated as follows:

1. Restrict sample sizes to four and to multiples of five from four to 45 (NBS Tables include all sample sizes from two to 49); in standard notation: 4, 4(5)45;
2. Restrict values of p from 0.01 to 0.10 by intervals of 0.01; from 0.10 to 0.30 by 0.05; from 0.30 to 0.50 by 0.10; in standard notation: .01(.01).10(.05).30(.10).50.
3. Restrict decimal places from seven to three.

The special feature of these abbreviated tables is the inclusion of both cumulative and individual (exact) probabilities of numbers of defectives in the sample. Probabilities for an exact number of defectives in a sample are indicated by column headings including an x; those for cumulative probabilities by column headings including a c. Any entry in a cumulative probability column is the sum of the entries in the two columns immediately to the left in the same row. The user will immediately see that the sum is sometimes "incorrect" by one unit in the third decimal place (decimal points

*Tables of the Binomial Probability Distribution, NBS AMS6, Supt. of Documents, Government Printing Office, Washington, 25, D. C., 390 pp.
H. G. Romig, *50-100 Binomial Tables*, John Wiley and Sons, New York, 1953, 170 pp.

†These tables were prepared by the author when he was with the Air Materiel Command, USAF.

Binomial Probability Tables—n = 10

p	x=0	x=1	c=1	x=2	c=2	x=3	c=3	x=4	c=4	x=5	c=5	x=6	c=6	x=7	c=7	x=8	c=8	x=9	c=9	x=10	c=10
.01	904	091	996	004	1000																
.02	817	167	984	015	999	001	1000														
.03	737	228	965	032	997	003	1000														
.04	665	277	942	052	994	006	1000														
.05	599	315	914	075	988	010	999	001	1000												
.06	539	344	882	099	981	017	998	002	1000												
.07	484	364	848	123	972	025	996	003	1000												
.08	434	378	812	148	960	034	994	005	999	001	1000										
.09	389	385	775	171	946	045	991	008	999	001	1000										
.10	349	387	736	194	930	057	987	011	998	001	1000										
.15	197	347	544	276	820	130	950	040	990	008	999	001	1000								
.20	107	268	376	302	678	201	879	088	967	026	994	006	999	001	1000						
.25	056	188	244	282	526	250	776	146	922	058	980	016	996	003	1000						
.30	028	121	149	233	383	267	650	200	850	103	953	037	989	009	998	001	1000				
.40	006	040	046	121	167	215	382	251	633	201	834	111	945	042	988	011	998	002	1000		
.50	001	010	011	044	055	117	172	205	377	246	623	205	828	117	945	043	989	010	999	001	1000

were omitted throughout the tables proper—each set of three digits is to be understood to be preceded by a decimal point).*

As is implied above in the footnote to the above paragraph, probabilities for exact numbers of defectives are given in NBS Table I; cumulative probabilities for *at least a given number of defectives* are given in NBS Table II. The author preferred to tabulate probabilities for *at most a given number of defectives*, comparable to the statement of acceptance numbers in sampling inspection.

VARIOUS USES OF THE TABLES

Example 1. A sample of ten items is taken at random from a lot (a lot should be at least ten times the sample size) for which the process average has been established as 0.06 defective. What is the probability that the sample will contain (1) exactly three defectives; (2) not more than three defectives; (3) less than three defectives; (4) at least three defectives?

Solution: We have n=10 and p=0.06. For (1) exactly three defectives, in row p=0.06, column x=3, we find 0.017; for (2) not more than three defectives, use column c=3, and we find 0.998; for (3) less than three defectives, use column c=2, and we find 0.981; and for (4) at least three defectives the probability is 1 − (col. c=2) = 1 − 0.981 = 0.019.

*This apparent inaccuracy is a result of the principle used in rounding off the seven-decimal place values of the NBS Tables: a tape adding machine was used to obtain successive subtotals of the entries in NBS Table I, which were then rounded to three decimals. For example, for n=4, p=0.01 and c=1, the tabular value is 0.999, while the tabular values of the two columns to the left in this row are, respectively, 0.961 and 0.039, whose sum is 1.000, not 0.999. However, the seven-decimal place values from NBS Table I are 0.9605960 and 0.0388120, whose roundings are 0.961 and 0.039, but their sum is 0.9994080, whose rounding is 0.999. All other "discrepancies" arise in the same way.

Binomial Probability Tables—n = 5

p	x=0	x=1	c=1	x=2	c=2	x=3	c=3	x=4	c=4	x=5	c=5
.01	951	048	999	001	1000						
.02	904	092	996	004	1000						
.03	859	133	992	008	1000						
.04	815	170	985	014	999	001	1000				
.05	774	204	977	021	999	001	1000				
.06	734	234	968	030	998	002	1000				
.07	696	262	958	039	997	003	1000				
.08	659	287	946	050	995	004	1000				
.09	624	309	933	061	994	006	1000				
.10	590	328	919	073	991	008	1000				
15	444	392	835	138	973	024	998	002	1000		
.20	328	410	737	205	942	051	993	006	1000		
.25	237	396	633	264	896	088	984	015	999	001	1000
.30	168	360	528	309	837	132	969	028	998	002	1000
.40	078	259	337	346	683	230	913	077	990	010	1000
.50	031	156	188	313	500	313	813	156	969	031	1000

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Example 2. For prescribed sample sizes, binomial tables also provide a rapid means of plotting operating characteristic curves for sampling plans. If we have an acceptance number of zero, use entries in an $x=0$ column to find the probability of acceptance (p_A); for any other acceptance number, use entries in the column headed by c=acceptance number. For example, if in MIL-STD-105A, Inspection Level I is being used, and lots run from 111 to 180 pieces, the single-sample size is ten. For an AQL of 10.0, the acceptance number is two, so by plotting probabilities in the $c=2$ column against the various lot fractions defective, the operating characteristic curve can be obtained.

Example 3. In contract to the column-wise use of the tables for plotting OC curves, the rows of the tables (using only the entries in columns giving individual values of probabilities; i.e., those headed by x's) provide a means of constructing histograms for binomial distributions. A histogram can be constructed as follows choose values of n and p, say $n=5$ and $p=0.15$. On a scale, mark off points to répresent $x=0, 1, 2, 3, 4$ (no tabular value is given for $x=5$ because $(0.15)^5=0.0000759<0.0005$). At these points erect ordinates proportional in length to 0.444, 0.392, 0.138, 0.024, 0.002, these being values of the probability read off in the tables for $n=5$ and $p=0.15$. With 0.444 as height, construct a rectangle whose base extends from −0.5 to 0.5; with 0.392 as height, construct a rectangle whose base extends from 0.5 to 1.5; continue similarly with the remaining perpendiculars. The total area of the five rectangles is 1.000; which corresponds to the probability of observing 0, 1, 2, 3, or 4 defectives when any sample of size $n=5$ is drawn from a (large) population or process that is operating at a 15 percent level of defectives. (We must remember that the probability of observing five defectives under the stated conditions is less than 0.0005.) The average value of x can be obtained in either of two ways:

1. Find the products of the integer values of x and the corresponding probability and then find their sum: (0)(0.444) + (1)(0.392) + (2)(0.138) + (3)(0.024) + (4)(0.002) = 0.748.
2. Find $np=5(0.15)=0.75$. This method is always correct for the binomial distribution. The method given in (1) is correct for any distribution.

EXTRACT FROM AUTHOR'S TABLES

Space does not permit publication of the complete tables computed by the author. Only the portion for $n=5$ and $n=10$ accompany this paper. These show the reader the format used. Copies of the complete table are available from the author at 1507 Abbott Avenue, Ann Arbor, Michigan.

When Does 1% Trouble Equal 30% Trouble!

W. P. KOECHEL

Tung-Sol Electric Inc.

MANY of us are in industries where a multiple number of our produced items are simultaneously used in an end-product device; i.e., as many as 30 tubes can be used in one TV set, or as many as 100 condensers is not unusual in a single electronic device.

If the end-use device simultaneously utilizes any number of items in such a way that the failure of just one component will cause the entire apparatus to be entirely inoperative, then we are inadvertently involved in the laws of compound probability and *one percent trouble may easily equal 30 percent trouble!*

PROBLEM 1. Let's trace the strange paradox of one percent leading to 30 percent trouble. A manufacturer of a five-tube radio set has noticed that five percent of his assembled sets are inoperative due to defective tubes and jumps to the conclusion that the tubes he purchases must be five percent defective. The same manufacturer later starts manufacturing 30-tube TV sets and notices that ten percent of his assembled TV sets are defective due to inoperative tubes. Doesn't this prove that the quality of incoming tubes to the plant is now worse than what it was when he was manufacturing radio sets?

ANSWER: No, this does not prove that tube quality is worse, but by coincidence proves that the quality level is better!

If a product such as radio tubes is produced with a quality level of one percent defective and five tubes are installed in each set, then due to the laws of probability, the chances of set failure are increased to 4.9 percent. (That is, any random selection of five tubes will result in one or more defects 4.9 percent of the time.)

If the tube quality level remains at one percent, and a set manufacturer begins the production of 30-tube sets, his chance of getting inoperative sets because of tube failures will increase to an average of about 25 percent. That is, about 25 percent of the random selections of 30 tubes would contain one or more defectives.

CONCLUSION: Since the questioner stated that he was getting only ten percent failures of his 30-tube sets (due to tubes), this indicates that the tube quality level must be about 0.33 percent. In other words, his tube suppliers who had been supplying tubes with a quality level of one percent are now supplying a much better quality level of about 0.33 percent. A tube quality level of approximately 0.33 percent will result in one or more defective tubes in a 30-tube sample about ten percent of the time.

A convenient chart for predicting the number of assembly failures due to the percent defective of individual components *in any assembly* is shown in Fig. 1. This is the chart we used to supply the preceding answers to Problem 1.

PROBLEM 2: Why should a greater percentage of set failures occur in 30-tube sets than in five-tube sets as mentioned in the first problem?

APPROACH: If a group of tubes are running one percent inoperative and such tubes are selected at random and installed in a five-tube set, this is in effect equivalent to selecting a "five-tube sample." The question therefore arises as to what percentage of the time may we expect at least one defective tube in a five-tube sample.

The probability P_a of getting zero defects in five tubes, with process average $\bar{p}$ is $(1 - \bar{p})^5$, or in general of getting zero defects in n tubes is $(1 - \bar{p})^n$. In this case, $n = 5$ and the process average is $p = 0.01$. Therefore, $P_a = (1 - 0.01)^5 = 0.951$ or a probability of 95.1 percent of finding no defects in a sample of five. This in turn means a probability P_r of $(1.00 - 0.951) = 0.049$ or 4.9 percent of finding samples of five with one or more defectives.

By repeating the foregoing process for various assumed process averages (p values) and assumed group sizes (n) we can create operating curves* such as shown in Fig. 1. For example, by reference to the figure, it will be noted that if incoming tubes to a set manufacturer are one percent defective, then 4.9 percent of the time the manufacturer will find defective sets due to at least one defective tube in each five-tube kit.

With the same incoming quality level of tubes (one percent) the set manufacturer would find 25 percent of the sets bad if he were manufacturing 30-tube sets. Since the questioner's problem stated that in a 30-tube set he was getting ten percent failures, this indicates, as noted from the curve, that the quality level of the incoming tubes must be about 0.33 percent. Thus, to obtain the probable set failure value for any given percent defective tubes, it is merely necessary to regard the number of tubes in the set as a sample size. Then determine from Fig. 1 the probability of finding one or more defective tubes out of this sample size.

Although the foregoing explanations have referred to tubes, the same chart can be used for any other product; i.e., if a manufacturer is purchasing small condensers which are running 0.2 percent defective, and 100 of these condensers are used in one assembled device, then he might expect 18 percent failure out of many completed assemblies.

As an example of other uses of Fig. 1, let us assume that a chain manufacturer makes strength tests on individual links. Assume further that 0.2 percent of individually tested links fail at a 10-lb. pull and that one percent fail at a 50-lb. pull.

PROBLEM: What would be the overall expected failure of a large number of chains, if each were composed of 50 links selected from a group with the foregoing failure values?

ANSWER: Referring to the chart under 0.2 percent failure, this inter-

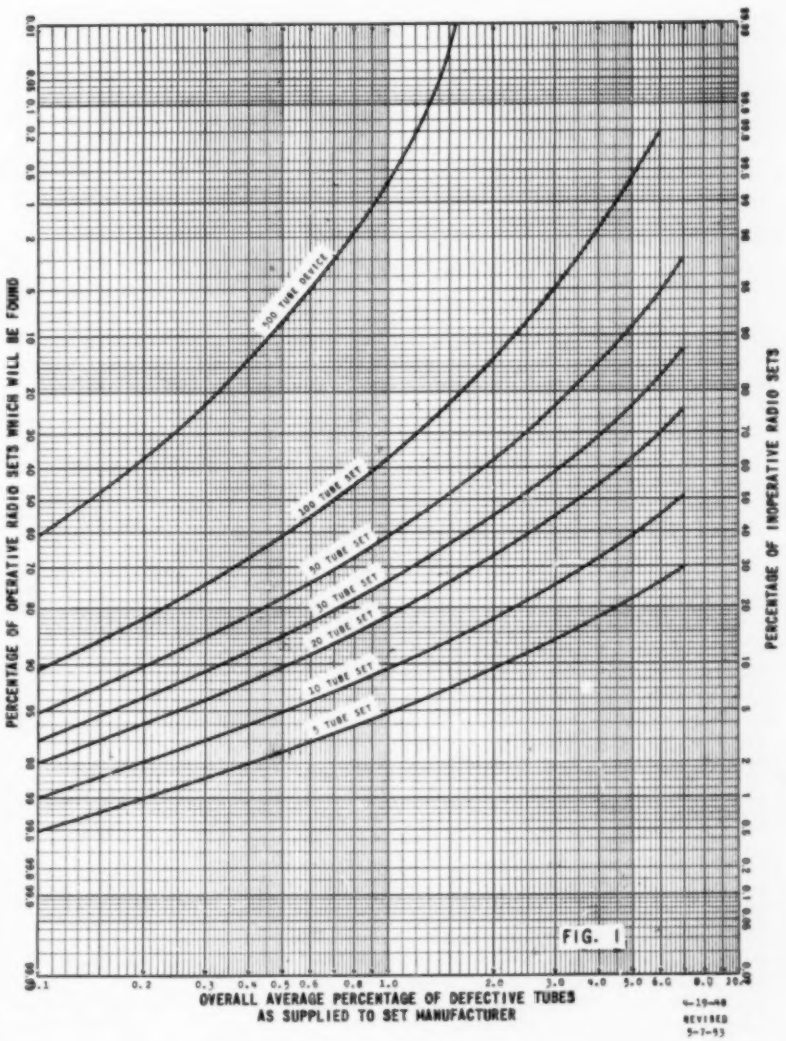
PERCENTAGE OF OPERATIVE RADIO SETS WHICH WILL BE FOUND
PERCENTAGE OF INOPERATIVE RADIO SETS
100 TUBE DEVICE
100 TUBE SET
50 TUBE SET
30 TUBE SET
20 TUBE SET
10 TUBE SET
5 TUBE SET
FIG. 1
OVERALL AVERAGE PERCENTAGE OF DEFECTIVE TUBES AS SUPPLIED TO SET MANUFACTURER
6-19-48 REVISED 5-7-53

Figure 1—Probality of Finding Inoperative Radio Sets Due to One or More Inoperative Tubes in Kit

*Satisfactory values of $(1 - \bar{p})^n$ can be obtained from the tables *Poisson's Exponential Binomial Limit*, E. C. Molina, D. Van Nostrand, New York, 1947.

sects the n = 50 curve at the ten percent failure point. Therefore, we predict an average of ten percent of finished 50-link chains would fail at a pull of 10 lb. Similarly it will be observed that 40 percent of 50-link finished chains would be expected to fail at 50 lb.

NOTE 1. It is very important to remember that the foregoing applies only where the components are simultaneously in use and where the failure of any one component would cause the entire assembly to be inoperative.

If, for example, 50 switches were used in some electronic device, but the operation of the device was such that only one or two switches were used at a time, then it would not be valid to use the chart shown in Fig. 1.

NOTE 2. In addition, it should be noted that the chart is based on the premise that the various components involved have approximately the *same quality level.* Thus, assume that the 30 tubes used in a TV set are divided as follows:

10 tubes with quality level of 1%,

20 tubes with quality level of 0.4%.

Direct computation (making allowance for the two groups) gives an expected value of 16.55 percent. A weighted average of the two groups is

$$\frac{10(1) + 20(0.4)}{30} = 0.6.$$

If we enter the chart with n = 30 and p = 0.6 percent, we estimate the number of TV set failures to be 17 percent.

Local Section News

"... BUT NOT FORGOTTEN"

ALBANY The Dec. 8 meeting of this section was held at Panetta's Restaurant at Menands, N. Y., and featured Brainard Sooy, Gardner Board & Carton Co., as the after-dinner speaker. Mr. Sooy spoke on "SQC in Paper Making and the Graphic Arts." He also set a record at this section. Of the 48 members and guests present at the meeting, 45 rated the speaker "excellent" and three rated him "good."

Frank Wilcoxon spoke at the Jan. 12 dinner meeting on the subject "Some Rapid Approximate Statistical Procedures." Ralph E. Wareham, past president of ASQC, was a guest at this meeting.

The section is pleased to announce that through the efforts of the education chairman, J. H. Davidson, arrangements were made with Union College, Schenectady, to offer a course in operations research during the spring semester. The course is being held on Monday and Wednesday evenings at 7:00 and is being taught by Paul Gunther, General Electric Co.

BOSTON The January meeting of this section presented as the speaker A. C. Rosander, Bureau of Internal Revenue. His address was divided into two parts, the first covering what he felt were the various applications of statistics to accounting. His main stress in this area was the applications of probability theory, particularly sampling, to auditing, and the infrequency with which this is done. The second part dealt with some of the probability controls used by the government in its tax administration. After his formal talk he showed the group some of the probability displays he uses in his courses at George Washington University.

BUFFALO Mason E. Wescott, Rutgers University, spoke at the regular meeting of this section on Jan. 25. Dr. Wescott told the section about the experiences of the UN statistical quality control team which was sent to India in the fall of 1952.

BUZZARDS BAY Lester Glickman, USN Central Torpedo Office, presided at the Feb. 9 meeting of this section which was held in the Personnel Building, Hathaway Mfg. Co., New Bedford. The speaker at the meeting was Warren Purcell, Rath and Strong, Inc.

CHICAGO The Jan. 20 meeting of the section was a very interesting one with R. I. Tenney, Wahl-Henius Institute, leading off with a good discussion of "SQC—a Radar for Brewery Management." The second hour of the afternoon session was on "Controlling Process Variables at International Harvester." The evening was devoted to a panel discussion on "Quality Control in the Pharmaceutical Industry." Participants were Dr. Harry E. Sargen, Karl Bauer and Jesse Owens, all of Abbott Laboratories. This was further evidence of how SQC can work everywhere. SQC "duz" everything.

The second in the series of advanced sessions was held at Navy Pier on Feb. 3. The general topic of differences in variances was the theme of the meeting. An extremely able job was done by Dr. Marjorie Sutherland with "Significance of Differences in Variances" and also by Peter K. Kuffner, USAF, on "Significance of Differences in Proportions."

CLEVELAND On Feb. 5, this section held its regular monthly meeting. The speaker was Dorian Shainin, Rath and Strong, Inc. Mr. Shainin's topic was "Tolerance Accumulation Problems."

On Jan 28, the executive committee of the section held a meeting at the Cleveland Engineering Society Building.

On Sunday, Feb. 7, the educational committee of this section put on a half-hour television program over WNBK, Channel 4. This program was produced in co-operation with the Cleveland Technical Society's Council and was directed at creating an interest in the field of quality control among high school students. This series is entitled "Adventures in Engineering."

Programs representative of different branches of the engineering profession are televised to familiarize high school students with the scope of the various branches of engineering as a possible career.

Wendell Abbott as chairman of the educational committee was in charge of the organization of the program and also participated in its presentation.

DAYTON L. R. Harrington, King-Seeley Corp., addressed this section's Jan. 20 meeting. Mr. Harrington's subject was "Quality Concepts and Their Effects on Quality Control."

DELAWARE Speaking before the largest meeting of the season, Lawrence M. Debing of Monsanto Chemical's Plastics Division, discussed "Process Control in Chemical Operations." A lively question and discussion period followed the talk.

DENVER Richard H. Blythe, Air Defense Command, presented a talk on "Beyond the Control Charts" at the Feb. 9 meeting of this section.

Mr. Blythe, who is a member of the section, pointed out some of the economic aspects of multistage and stratified sampling of finite populations, using timber volume problems of the U. S. Forest Service as examples.

To point out the close and often overlapping relationship between quality control and operations research, he presented the problem of purchasing an acoustical aid for the Ground Observer Corps. By means of a properly designed statistical experiment, the Air Defense Command was able to evaluate the equipment using a small sample tested under numerous operating conditions.

ERIE Our Jan. 6 program featured Quentin Dobras of General Electric's Lighting Institute at Nela Park in Cleveland. Mr. Dobras substituted for E. A. Lindsay, who originally had been scheduled. We were all given something to think about regarding "specialized lighting for inspection and control." Unfortunately bad weather hampered our turnout at this meeting.

Our three study groups—two in Erie and one in Corry, Pa.—completed the basic course in statistical quality control during January. H. S. Herrick, course director, announced that 73 of the 101 enrolled in the classes successfully completed the required units of work. Seventeen area industries were represented in the course. Special wallet sized certificates were issued to the 73. The certificates which carried the sanction of the Erie section were designed by Dave Ferrell, Erie Resistor Co. Such a continued interest has been shown in the area that the education committee has announced that the course will be repeated in the fall of 1954.

EVANSVILLE-OWENSBORO The January meeting of this section was held in the General Electric Plant conference room at Owensboro. Charles Latimer, Nickey Bros. Lumber Co., made an interesting presentation of some problems encountered in the lumber industry. He illustrated his talk with slides showing various types of control charts they have found effective. Following the meeting the members spent about an hour asking additional questions and enjoying an informal conversation with the speaker.

INDIANAPOLIS All members had a very instructive and pleasant evening at this section's Jan. 19 dinner meeting. Miss Bonnie Small, Western Electric Co., Allentown, Pa., presented "The Inside Story of Quality Control." Joe Ellis, Bloomington, Ind. also gave an entertaining talk on the lighter side.

The spring semester of the section's training program started on Jan. 26. Three classes are being offered this semester. The first class on fundamentals and control charting is being taught by Frank Weeks, Allison Div., GMC, and Robert Bacon, Dunnington Mfg. Co.; the second on sampling, by W. C. Bissing, Eli Lilly and Co.; and the third entitled "Probability at Work," by Dr. E. P. King, Eli Lilly and Co.

INDIANAPOLIS Lafayette Subsection The Indianapolis section takes great pleasure in announcing the formation of its first subsection which will hold meetings in Lafayette. To complete the organization, temporary officers for the subsection have been appointed as follows:

Chairman:	Irving W. Burr Purdue University
Vice Chairman:	Harold E. Wilson Ross Tool & Gear Co.
Secretary:	John Kamstra Fairfield Mfg. Co.

KANSAS CITY The January dinner meeting of the section was attended by 60 members and visitors. J. A. Harrington, Chief Engineer of the Do All Co., who was the speaker of the evening, discussed the relationship of inspection gages to quality control. He stressed the requisite of accuracy of inspection gages to attain reliable statistical records. It was noted that there is a universal interest in the furtherance of the adoption of the light wave as a standard for linear measurement. The Do All Co. displayed some of their more recent developments in precision gaging and instrumentation.

LINCOLN This section held a dinner meeting on Jan. 15 at the Capital Hotel. Addressing the meeting of 23 members and five guests was Prof. Miles Barnard, University of Nebraska. Professor Barnard gave an excellent and interesting talk on "The Operating Characteristic Curve."

LOS ANGELES The use of quality control in the field of accounting and industrial management was the topic discussed at the Feb. 17 meeting of this section. Roland L. Roy, associate, and Kenneth L. Ledderman, consultant with Booz, Allen, Hamilton Co., were the guest speakers.

LOS ANGELES San Bernardino Subsection At the Feb. 4 meeting of this subsection Harry G. Romig explained the use of a demerit system of quality rating. In addition the Johns-Manville Co. film on quality control was shown by J. W. Croft.

The group reports that attendance at meetings has been exceptionally good and that if their membership growth continues at its present rate they expect to petition for full section status in the near future.

MILWAUKEE This section held its second annual Industrial Clinic for Quality Control on Wednesday Feb. 3 at the Wisconsin Hotel. The sessions dealing with a variety of quality control problems in several different fields were well received by the 125 persons attending the clinic.

The clinic was opened with a talk on "Quality Control as a Profession" by Dr. Paul J. Mundie. The noon luncheon was highlighted by an address by J. E. Obernesser, works manager of International Harvester's Milwaukee Works. His topic was "Customer Satisfaction Keynotes Quality Control Programs."

At the regular monthly meeting of this section on Jan. 18 Dorian Shainin, Rath and Strong, gave an interesting talk on the application of SQC techniques to various engineering functions.

MILWAUKEE Winnebago Subsection On Jan. 15 in Appleton Carl E. Noble, Kimberly-Clark Corp., spoke at the first scheduled program meeting of this subsection. He addressed the 45 members and guests on the subject of the "Statistical Quality Control Program."

At the business meeting following the program the following officers were elected:

Chairman:	Alfred H. Fenner Kiekhaefer Aeromarine Motors
Vice Chairman:	Ray N. Holland Marathon Corporation
Secretary:	Edward Schuch Fairmont Foods, Inc.
Treasurer:	Paul A. Ebert Kohler Co.

MUNCIE This section was privileged to spend the evening of Jan. 23 with G. G. Parkin, Minnesota Mining & Mfg. Co. His address, "Tests of Significance in Industrial Processing," was a stimulating view of some old and new techniques skillfully applied.

NORTHEASTERN INDIANA The regular monthly meeting of this section was held at the Fort Wayne Chamber of Commerce on Thursday evening, Jan. 18.

L. B. Brewer, Salisbury Axle Works, was the sponsor for the meeting. Mr. Brewer arranged to have D. G. Browne of The Broderick Co., Muncie, as the guest speaker.

PHILADELPHIA Our January meeting featured R. F. Drenick, R.C.A., who spoke on "Quality Problems in Life Testing." Dr. Drenick discussed some of the difficulties in establishing life tests designed to insure the customer a specified operational life. His adroit sense of humor made his talk even more interesting to the well-attended meeting.

Our change of time for the problem clinic went into effect for the first time in January and the new time of 6:30 may have had some bearing on the increased attendance.

SAN DIEGO Resistance welding was the general subject covered at the Jan. 11 meeting of this section. The program, arranged by Vern Scherkenbeck, was a double-header affair. The first part dealing with the welding of various steel alloys including stainless was given by Frank Harkins, Solar Aircraft; the second part on aluminum alloy welding was presented by Raymond Vredenburgh, Rohr Aircraft. A lively half-hour discussion session followed the meeting.

SAN FRANCISCO BAY AREA Prof. Gerald Lieberman, Stanford University, conducted a quality control training session in San Francisco on Jan. 11. Topic for discussion for the evening was Sampling Inspection by Variables. Prof. Lieberman presented new developments in variables plans based on the average range and with both known and unknown standard deviations.

SALT LAKE CITY This section has just completed circulating 100 copies of the Navy ordnance booklet, "An Introduction to Statistical Quality Control." Several of the copies were given to the students of an SQC class being held at the University of Utah.

The meeting of Feb. 10, was highlighted by talks given by two men from Hill Air Force Base. Don Goodfellow, Chief of Statistical Analysis Branch, and William Umpleby, Chief of Process Analysis Branch, discussed some practical examples of substantial cost savings through use of quality control.

During the month one of our members, Osmund Harline, presented a short training session, "Some Fundamental Statistical Concepts," to a group of United Air Lines employees engaged in quality control work. The presentation was very well received and is the type of activity upon which good public relations between the local section and the industrial community are built.

SCRANTON-WILKES BARRE At the Jan. 21 meeting of this section Prof. McCord, Penn. State University, outlined various courses that could be offered on inspection and quality control. As a start on the program, a 32-hour introductory course will be given covering the formulation, use and operation of basic statistical techniques as applied to quality control charts in manufacturing operations. The classes which are being offered this spring are under the direction of our section chairman, Carl Larson.

SEATTLE On Jan. 12, Norman Steele, Boeing Airplane Co., spoke on "Quality Control in the Chemical Industry."

SOUTHERN CONNECTICUT S. R. Calabro, Federal Telephone and Radio Co., addressed this section on Jan. 13. He discussed "Quality Control as a Tool for Interchangeability."

Education courses sponsored by this section started in Bridgeport, Waterbury, and Stamford on Jan. 20. These are eight week quality control courses including fre-

quency distribution, control charts, and sampling plans. These courses are conducted by John A. Rovegno, Vacuum Cleaner and Fan Motor Div., General Electric Co., Bridgeport; G. C. Baldwin, Scoville Manufacturing Co., Waterbury; and Philip Worth, Electrolux Corp., Stamford.

SOUTHERN TIER Our speaker for the October meeting was Ralph E. Wareham, Quality Control Consultant, whose subject for this meeting was, "Managing Your Quality Control Program."

Frank G. Norris, a member of the editorial board of *Metal Progress*, was the speaker at our Nov. 9 meeting which was a joint session of ASQC and ASME. He spoke on "Quality Control for the Metallurgists," at the meeting which was held at the Willard Straight Hall of Cornell University, Ithaca.

For its Dec. 8 meeting, Dr. A. V. Feigenbaum, General Electric Co., spoke on "Company Education on the Quality Problem."

The January meeting was well attended by members and guests who came to hear our own Paul Robert, IBM Corp., talk on "Tolerances in the Metal Working Industry."

SOUTH TEXAS On Jan. 21, A. R. Burgess, Head of the Industrial Engineering Dept. of A & M College of Texas, spoke to the meeting of the section which was held in Houston. His topic "To Err is Human."

SYRACUSE The January meeting is always a "milestone" affair for this section and this year it will be an exceptionally memorable one.

The meeting consisted of a "twin bill." Following the dinner the first event of the evening was the formal presentation of certificates of completion to the people who had taken any one of the three quality control courses given by the section during the fall semester. The group of "graduates" this year was one of the largest in the six years that the courses have been given.

The second event was a "What's Your Problem?" panel discussion conducted by six members of the section. Panel members were: Martin Brumbaugh, Bristol Laboratories; Leon Bass, General Electric Co.; Bradford Vineall, Easy Washing Machine Corp.; Ralph Swalm, Syracuse University; Francis Donahue, Nestle Inc.; Joseph Sadowski, Crucible Steel Corp.

The panel offered solutions to quality control problems which had been submitted in advance and a very spirited meeting ensued.

Having completed the first semester of quality control courses with one of the largest enrollments and smallest number of "drops" in six years this section started the second semester on Feb. 1 with high spirits.

Again three courses in SQC are being given in evening sessions at Smith Technical High School. The first course "Applied Techniques of Elementary Quality Control" will be taught by Hugh Wallace, General Electric Co.; the second "Applications of Sampling Plans and Significance Testing," by F. Levere Winne, Oberdorfer Foundries, Inc.; and the third "Applications of Variance Analysis and Special Topics," by Albert Edgar, Bristol Laboratories, Inc.

TORONTO "The QC Manager's Responsibilities to Purchasing and the Vendor" was the subject of the talk given by L. R. Harrington, King-Seeley Corp., in the Mechanical Building, University of Toronto, on Jan. 13. His talk centered around the statistical aspects of the safety factor between mating tolerances in straight assembly. A very interesting discussion ensued on the quality concepts of conformance to specifications and also product requirements.

The Toronto section members visited the Dufferin Works of the Canadian General Electric Co., Ltd., on Jan. 27 to see several kinds of incandescent lamps in production. After the tour some of the quality control procedures were explained by Mr. C. Hilditch.

UNIVERSITY OF WESTERN ONTARIO Barrie Bassett and Morris Nicholson both of Timken Roller Bearing Co., presented a two-day training session to the London group of this section on Dec. 4-5. They also presented the session to the Kitchener group on Jan. 15-16.

On Jan. 27 the London group met at the General Motors Diesel Plant. Following the plant tour Joseph Howard, chief inspector, led a discussion on some of the company's quality problems.

On Jan. 20 the Windsor group met for a tour of the Essex Wire Corp. Plant. Following the tour the members viewed the film "Managing Quality" by Ford Motor Co. of Canada.

WESTERN MASSACHUSETTS The Jan. 12 meeting was attended by 85 members and guests, with most of the guests being members of the Purchasing Agents Association of Western Massachusetts, Inc. Nelson G. Meagley, Willys Motors, talked on "Vendor Certification." Mr. Meagley illustrated the advantages to be gained not only by the purchaser but also by the vendor when vendor certification and the entailed use of statistical quality control is instituted. He aptly pointed out methods for controlling and assuring quality.

WORCESTER On Thursday, Jan. 21, Wade R. Weaver, Republic Steel Corp., addressed a turnout of 75 members and guests at a dinner meeting of this section. His talk was significant in light of the many questions which are being asked regarding "The Breadth and Scope of Quality Control." Mr. Weaver's talk dispelled any doubts concerning the far reaching application of quality control.

". . . CAST THEIR SHADOWS BEFORE"

CHICAGO The last regular meeting of the year is scheduled at the Furniture Mart at 2:30 on Mar. 24. The general theme is Quality Control Training. There is to be a panel to lead a discussion and to answer any and all questions from the floor. Also of considerable interest is the planned talk by Nicholas Relick, Purdue University, on SQC concepts in lay language. This promises to be a red-hot session.

The third meeting of the Advanced Educational Series will be held at Navy Pier at 7:15 on Apr. 7. The theme is to be Analysis of Variance. If the previous meetings in the series are considered as an indication of the value of this one, this is certainly a must on all your programs.

CALENDAR OF MEETINGS -- MARCH 20, 1954 -- APRIL 19, 1954

*Indicates meeting dates in March

SECTION	DATE	MEETING PLACE	TIME	SUBJECT	SPEAKER
Albany	12	———	——	SQC Techniques in Time and Method Analysis	E. E. Schiesel, Mattatuck Mfg. Co.
Allentown-Bethlehem	15	———	——	Control Charts—a play by section members	———
Baltimore	—	———	——	No meeting scheduled	———
Buffalo	29*	Crosby Hall, Univ. of Buffalo	——	QC in the Electronics Industry	Leon Bass, General Electric Co.
Central Illinois	16	Decatur, Ill.	——	Evening Meeting—subject to be announced	———
Chicago	24*	Furniture Mart	2:30	Quality Control Training	Nicholas Relick, Purdue University
Cincinnati	—	———	——	No meeting scheduled	———
Cleveland	2	Cleveland Engineering Society	6:30	How Quality Control Helps Supervision	E. L. Fay, Deere & Co.
Columbus	8	Southern Hotel	6:30	What Is the Quality Control Job?	J. M. Juran, Management Consultant
Dallas-Ft. Worth	8	Arlington State Coll., Engr. Bldg.	8:00	Application of Machine Control Chart Theories	B. L. Lubelsky, McAllester Ordnance Depot
Dayton	7	Nat'l Cash Register Co., Audit.	8:00	What Is the Quality Control Job?	J. M. Juran, Management Consultant
Delaware	1	Hob Tea Room	6:30	Control of Accuracy and Precision of Ind. Test and Analyses	J. A. Mitchell, Tennessee Eastman Co.
Denver	5	———	——	Quality Control as an Administrative Aid (tentative)	C. A. Bicking, Office Chief of Ord.
Erie	6	———	——	Quality Control at B. F. Goodrich	L. A. Freeman, B. F. Goodrich
Hartford	—	———	——	No meeting scheduled	———
Indianapolis	—	———	——	No meeting scheduled	———
Kansas City	14	Railroad Room, Union Station	7:00	QC Problems of Air Lines	Dale Lobsinger, United Air Lines
Lansdale	15	———	——	QC in Electronics	Leon Bass, General Electric Co.
Lincoln	9	Capitol Hotel	——	Subject to be announced	H. R. Harrison, Collins Radio
Los Angeles	—	———	——	No meeting scheduled	———
Louisville	12	———	——	QC of Precision Parts	C. E. Hoover, Perfect Circle Corp.
Metropolitan	22*	Hotel Douglas	7:00	Records, Reports and Clerical Methods in QC	———
	14	Nat'l Cash Register	7:00	Statistical Quality Control in New York	———
Michigan	—	———	——	No meeting scheduled	———
Milwaukee	19	Marquette Univ. Bus. Adm. Bldg.	7:30	Techniques for Process Trouble-Shooting	L. A. Seder, Quality Control Consultant
Minnesota	5	Curtis Hotel	6:30	Management Controls	J. M. Juran, Management Consultant
Montreal	24*	———	——	Effort vs Return in Applying Stat. Methods	A. W. Birnie, Canadian Industries, Ltd.
				Getting the Most Out of Your Experiments	G. L. Cockhill, Shawinigan Chemicals, Ltd.
	14	———	——	SQC in Engineering Research and Development	P. S. Olmstead, Bell Telephone Laboratories
Muncie	6	L. A. Pittenger Student Center	6:30	What Is the Quality Control Job?	J. M. Juran, Management Consultant
New Haven	15	Chamber of Commerce Audit.	——	Tolerance Corrections	E. B. Haden, Esterbrook Pen Co.
Northeastern Indiana	8	———	——	———	D. A. Dalton, Dalton Foundries
Parkersburg	6	Chancellor Hotel	8:00	A Short Cut Method of Using Lot Plot	J. F. Greacen, Sr. Bristol Instrument Co.
Philadelphia	16	Franklin Institute	——	Marginal Problems of QC	W. A. MacCrehan, Lord Baltimore Press
Pittsburgh	23*	Sheraton Hotel	6:30	Getting Ready for Acceptance Sampling	J. H. Toulouse, Owens-Illinois Glass Co.
Rochester	6	Chamber of Commerce Bldg.	6:15	Stat. Tech. Subgroup: Randomization	Arthur Dutton, Univ. of Rochester
St. Louis	16	Chouteau House, St. Louis Univ.	6:00	Sampling Inspection by Variables	D. F. Flanders, General Motors Corp.
San Diego	12	———	6:00	Purchasing a Quality Product	Rohr and Ryan, Solar
San Francisco Bay Area	26*	Stanford Campus	——	One-Day Quality Control Conference	———
Seattle	2-3	Univ. of Washington	——	Second Annual Pacific Northwest Conference	———
	13	Benjamin Franklin Hotel	——	To be announced	———
Southern Connecticut	14	———	——	The Operator Is Interested	J. F. Verigan, Atlas Powder Co.
St. Univ. of Iowa	15	Iowa-Illinois Gas & Electric Aud.	7:30	The Use of "c" Chart in Assembly Operations	J. E. Meyers, International Harvester
Syracuse	30*	———	——	Process Variables Studies	B. H. Lloyd, Canadian Industries, Ltd.
Toronto	24*	———	8:00	Plant Visit—Frigidaire Products of Canada, Ltd.	———
	10	McMaster University, Hamilton	——	All-Day Forum	———
Trenton	6	Rider College	8:00	Plant Trip	———
Utica	—	———	——	No meeting scheduled	———
Washington	24*	New Athens Restaurant	——	Producer Reliability vs Acceptance Inspection	———
Western Massachusetts	13	Hotel Sheraton, Springfield	6:00	SQC in Engineering and Development	P. S. Olmstead, Bell Telephone Laboratories
Worcester	15	———	——	Ladies Night	———

Plans are now being made for a conference in June. Subject of the conference is "Quality Control Charts on Quality of Sandwiches Eaten at a Picnic" or "Upper Control Limits on Ants in Sandwiches."

CLEVELAND On Apr. 2, E. L. Fay, Deere and Co., will speak to the section on the topic "How Quality Control Helps Supervision." Dinner will be at 6:30 at the Cleveland Engineering Society Building. The business portion of the meeting will begin at 8:00.

Plans are being made for a tour of one of the local breweries. A definite date has not been set for this tour, which will be a combination plant tour and social event.

Another plant tour is being planned for the Cleveland Diesel Engine Division of General Motors. No definite date has yet been established.

DAYTON J. M. Juran, Management Consultant, will address the section on Apr. 7, at 8:00 PM at the National Cash Register Co. Executive Auditorium. His subject will be "What Is the Quality Control Job?"

ERIE Our Apr. 6 speaker is to be L. A. Freeman, B. F. Goodrich Co., Akron. His topic has been announced as "Quality Control at B. F. Goodrich." Program chairman for this meeting is Fausto J. Adessi, Continental Rubber Works, Erie.

KANSAS CITY Dale Lobsinger, United Air Lines, will present to the section, at the April meeting, the quality control problems of air lines. It will be interesting to learn how the air lines have achieved their enviable safety record.

MILWAUKEE This section will hold its Apr. 19, meeting at 7:30 at Marquette University's Business Administration Bldg. Leonard A. Seder, Quality Control Consultant, will speak on "Techniques for Process Trouble Shooting."

MINNESOTA On Monday evening Apr. 5, this section will hold its monthly meeting at the Curtis Hotel. This will be a dinner meeting at 6:30 and we are looking forward with great pleasure in having as our guest J. M. Juran, who needs no introduction to ASQC circles.

MUNCIE Tuesday, Apr. 6, will mark an important date for eastern Indiana's industrial community when this section will welcome J. M. Juran, Management Consultant, who will discuss, "What Is the Quality Control Job?" The meeting will be held at 7:30 in the Pine Shelf Room of the L. A. Pittenger Student Center and will be preceded by a dinner meeting at 6:30.

PHILADELPHIA The April meeting will be held on Friday the 16th and W. A. MacCrehan, Lord Baltimore Press, will talk on "Marginal Problems of Quality Control." The meeting will be held at our usual place, Franklin Institute. Also we will have the Problem Clinic at 6:30.

ST. LOUIS March 19. Too late for most of you, but you're welcome if you can make it. Tour of Cook Imperial American Wine Co., St. Louis. Champagne for all.

Apr. 16. Donald F. Flanders, Allison Div., GMC, will be the speaker. Mr. Flanders will speak on the subject, "Sampling Inspection by Variables." The usual social hour and dinner will be at 6:00, the meeting at 8:00. Chouteau House, St. Louis University.

SEATTLE This section will hold its next meeting on Apr. 13, at the Benjamin Franklin Hotel. The program is not yet final and will be announced later.

SOUTHERN CONNECTICUT J. Frederick Verigan, Atlas Powder Co., will discuss "The Operator Is Interested" at the Apr. 14 meeting. This is a practical discussion giving the necessary "selling" required to get quality control across—particularly to the operator.

SYRACUSE B. H. Lloyd, Canadian Industries, Ltd., will speak at the March meeting of the section on "Process Variables Studies." Members of the section are curious to hear Mr. Lloyd's talk which should be a good indication of the scope and intensity of statistical quality control in Canada.

TORONTO Mr. W. Lopak and the Frigidaire Products of Canada, Ltd. will be host to this section for a plant tour on Mar. 24 at 8:00 PM. The section will visit the company's Scarboro Plant No. 1 at Toronto.

WESTERN MASSACHUSETTS On Apr. 13, at 6:00 PM at the Hotel Sheraton in Springfield, Paul S. Olmstead, Bell Telephone Laboratories, will speak on "Statistical Quality Control in Engineering and Development." Dr. Olmstead has done pioneer work in statistical quality control and can always be counted on for something new and interesting.

"AS YE SOW . . ."

CLEVELAND The executive committee of the section has accepted the recommendation of the educational committee to put on another short course in general quality control techniques for people in the Cleveland area who have had a limited educational background.

DAYTON A series of round table discussions was inaugurated on Feb. 4 under the direction of Paul I. Bland and sponsored by the Education Committee. The subject discussed at the first meeting was the use of probability paper in industrial application. The topics for these meetings will be selected from the suggestions of members participating in the discussions.

EIGHTH NATIONAL CONVENTION June 9-10-11. Add June 8 beginning at 3:00 pm! Anheuser-Busch (Budweiser) has planned a gala afternoon and evening event! Be sure to return your request for invitations early and insure a "Never-to-be-forgotten Eve." The request is attached to the Convention Brochure which you will be receiving in the mail shortly.

So remember—St. Louis, 8th National Convention, June 8, 9-10-11, 1954.

SAN FRANCISCO BAY AREA With the cooperation of the committee on industrial engineering at Stanford University this section is offering a one-day Quality Control Conference which will be held at the university on March 26. Prof. Grant Ireson is general chairman of the conference, the first to be offered by this section. It is hoped and planned, however, to present these conferences as an annual event.

Topics and speakers for the March 26 conference have been chosen to appeal generally to management level interests. Opening with an address of welcome by F. E. Terman, Dean of the Engineering College, the conference will cover the following topics: "Cost Reduction Through Quality Control," by Prof. E. L. Grant, Stanford University; "Control Charts—A Tool to Save Dollars," by Wyatt Lewis, General Electric Co.; "Insuring Quality of Purchased Products," by Dorothy Biggs, Cutter Labs; "New Horizons in Quality Control," by Dale Lobsinger, United Air Lines; "Quality Control for the Smaller Plant," by Alan Eagle, Broadview Research & Development; "Quality Control in Maintenance Operations," by Alan Hull, United Air Lines; "Sampling Inspection by Variables," by Prof. Gerald Lieberman, Stanford University.

SEATTLE Methods of producing products or services of guaranteed quality will be discussed at the Second Annual Pacific Northwest Conference on Quality Control which is being presented by this section on Apr. 2-3 at the University of Washington, Seattle.

The program will begin on Apr. 2 with a training session on basic concepts of quality control, to be followed by a session on advanced techniques. The second day will be devoted to the presentation of papers by Prof. E. L. Grant, Stanford University; Dale L. Lobsinger, United Air Lines; Prof. Z. W. Birnbaum, University of Washington; and Eugene Goddess, Boeing Airplane Co. In addition H. T. Broderson, Johns-Manville Co., will show his company's film "Modern Quality Control."

The conference is being presented through the cooperation of the University's Colleges of Engineering and Business Administration. Dr. G. I. Butterbaugh, University of Washington, is chairman of this year's conference. Programs, registration forms or additional information about the conference can be obtained from Norman W. Steele, Jr., 701 North 100th Street, Seattle.

TORONTO On Saturday Apr. 10 this section is sposoring an All-Day Forum on Quality Control to be held at McMaster University in Hamilton.

The morning program will be devoted to a panel discussion on "The Organization of Quality Control." Dr. J. M. Juran, Management Consultant, will serve as moderator for the panel which will consist of J. B. Bassett, Timken Roller Bearing Co., J. G. Gardiner, Massey-Harris-Ferguson, R. J. D. Gillies, Case Institute, and J. K. MacKeigan, Dunlop Tire Co. Completing the morning program will be a showing of the film "Man with a Thousand Hands," a Canadian technicolor production of the Kitimat Power Project with commentary by Raymond Massey.

The afternoon program will be split into two series. The topics covered will be sampling inspection procedures by F. A. Bucksot, International Harvester Co., receiving inspection in the electronics industry by J. E. Manzer, Canadian General Electric Co., quality control in the chemical industry by B. H. Lloyd, Canadian Industries, Ltd. and SQC in textile processiong by N. L. Enrick, Institute of Textile Technology.

This is the first all-day forum to be presented by the section. Registration fee, including luncheon, is $7.50. Advanced registration forms and further information may be obtained from J. P. Orton, Metallurgical Department, The Steel Co. of Canada, Ltd., Hamilton, Ontario.

"FOR MANY ARE CALLED, BUT FEW ARE . . ."

BOSTON Miss Dorothea Looney, Polaroid, has been appointed the new secretary of this section, replacing A. F. Bezanson, Gillette Safety Razor.

CHICAGO Archie Jackson, president of this section, has resigned from this post because he has recently moved to the Detroit area to join the firm of Harmon S. Bayer Associates as a quality control consultant. Mr. Jackson was formerly with the Allen B. Wrisley Co. of Chicago.

Former vice president Harry R. Bennett, Automatic Electric Co., is the new president. The section secretary Marjorie Sutherland has also assumed the duties of vice president. Both Mr. Bennett and Dr. Sutherland were elected to their new duties by the board of directors of the section.

INDIANAPOLIS Donald F. Flanders, Allison Division, GMC, was recently elected vice president of this section to fill out the term of Dale A. Cue who resigned this post on Jan. 15. Mr. Cue is transferring his membership to the Milwaukee section, where he is now employed by the A. O. Smith Corp.

SIGNIFICANT DIFFERENCES

Plans are completed for a contest to be conducted by the Philadelphia section for the best paper on "Applications of Statistical Quality Control." Students from schools in the Philadelphia area will be eligible to compete.

Michael O'Hanlon, chairman of our employment committee is no longer connected with I.R.C. and anyone wishing to contact him can do so at 4510 Camden Ave., Pennsauken, N. J.

And from the San Diego section newsletter is this sage piece of advice . . .

"Don't miss our (Monday night) meeting because you have to sit up with a sick friend—Bring him along!"

For the next season the Western Massachusetts section plans to have widespread company representation on both the program and membership committees. By so doing the program can be better tailored to fit the entire area's needs and from this it can be expected that membership and meeting attendance will be improved.

Oliver P. Beckwith has recently joined the staff of Fabric Research Laboratories, Inc. at Boston, Mass. He will be in charge of a newly created quality control group. Mr. Beckwith was formerly director of quality control for Alexander Smith & Sons Carpet Co.

NOTICE

In accordance with the provision of the Constitution of the Society, the Nominating Committee for 1954 herewith reports the following unanimously chosen nominees for the Society officers in 1954-55.

President:
Raymond S. Saddoris
A. O. Smith Corporation
Milwaukee Section

Vice Presidents:
Arthur Bender, Jr.
Delco-Remy Div., GMC
Indianapolis Section
Paul A. Roberts
IBM Co.
Southern Tier Section
Julian H. Toulouse
Owens Illinois Glass Co.
Toledo Section

Executive Secretary:
Dorian Shainin
Rath & Strong, Inc.
Hartford Section

Treasurer:
Leon Bass
General Electric Co.
Syracuse Section

Each of the above nominees has expressed his willingness to accept if elected to the office for which he has been nominated.

MEMBERSHIP CORNER

As the end of the membership year approaches, the tendency to relax our efforts to acquire new members becomes prevalent. To combat this tendency the following thought should be kept in mind: The man who has problems in and responsibilities for the control of quality needs the help which membership in ASQC can give him regardless of the time of year.

As an inducement to encourage people to become members at any time of the year the Society established half-year memberships which may be taken at the option of members joining after January 1. Be sure to remind the members who exercise this option that they will receive only the corresponding issues of *Industrial Quality Control* back to January 1. But even more important, be sure to encourage them to include dues for the following year also. This will avoid the nuisance of being billed and having to remit dues for the following year within a few months after joining. It will also simplify the work of the national office at a critical time the following June. For new members joining the Society after May 1 this encouragement becomes a requirement. A new regulation of the Society states that new members entering after May 1 may sign up as half-year members in the current year, *only* if they also join for the following fiscal year.

This is also a good time to complete follow-up on any delinquent members. But remember that the provision for half-year memberships applies only to new members, not to former or delinquent members who can be reinstated only by paying back dues. It will be easier to do this follow-up work now, than it will after another membership year begins.

Make your section grow by making membership an all-year activity!

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AN ERROR TO NOTE

For the benefit of many of our readers an error has been noted in the Dixon and Massey text (*Introduction to Statistical Analysis*, McGraw-Hill) in Tables 9a and 9b, pages 320 and 321. Namely, the tables were transposed in printing. The table shown as the .80 confidence interval is actually the .90 confidence interval and similarly the one shown as the .90 confidence interval is actually the .80 confidence interval.

This correction was sent to us by Frank Proschan, Sylvania Electric Products, who first verified it with W. J. Dixon, one of the co-authors.

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POSITIONS WANTED

Address all replies to box number references to: American Society for Quality Control Room 5736, 70 East 45th Street, New York 17, N. Y.

QUALITY CONTROL COORDINATOR with seven years experience in quality control work, versed and experienced in the use of ASQC methods and procedures desires relocation. Resume sent on request. Reply to box 10E1 at the above address.

BRAIN FOR RENT—INDEFINITELY Statistical Quality Control man, one year experience in cigarette quality control, college graduate, Korean veteran, married, will relocate. Available June. Please reply to Box 10E2 at the above address.

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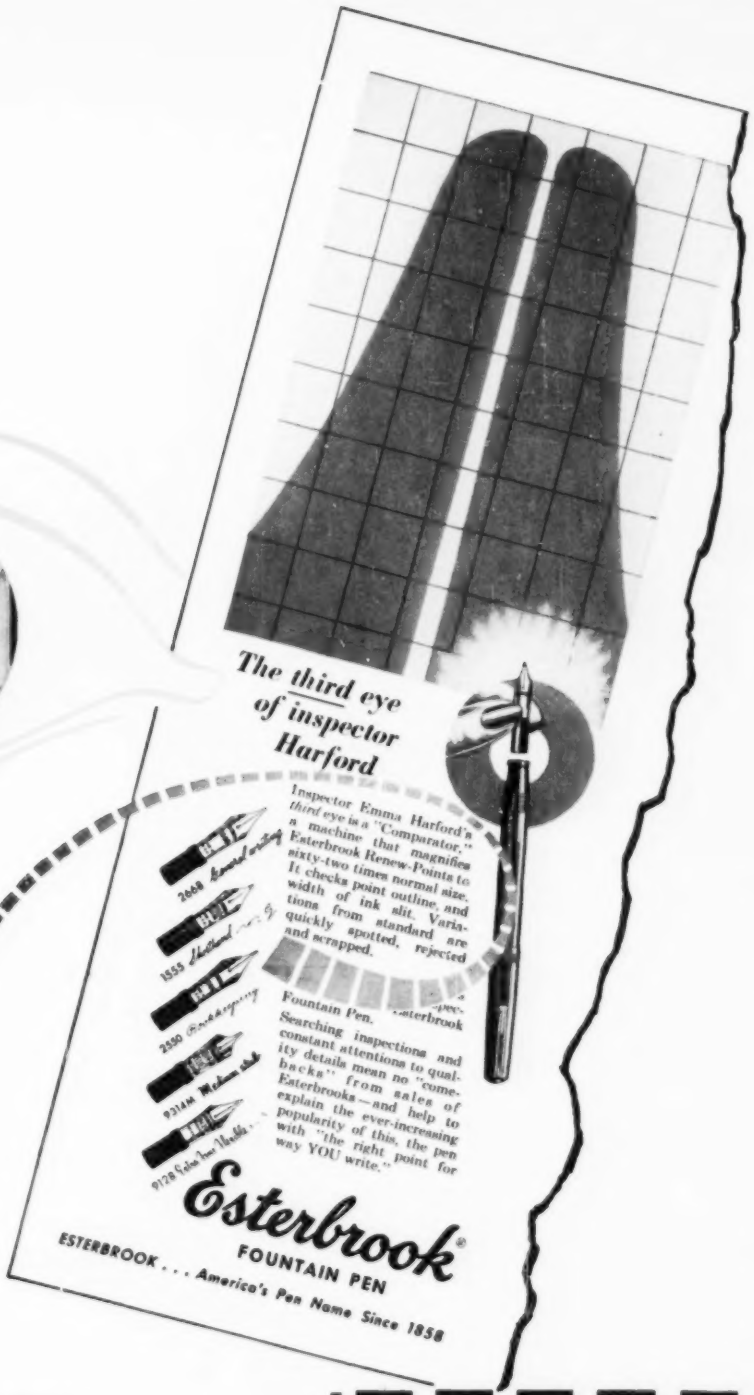
The third eye of inspector Harford
Inspector Emma Harford's third eye is a "Comparator," a machine that magnifies Esterbrook Renew-Points to sixty-two times normal size. It checks point outline, and width of ink slit. Variations from standard are quickly spotted, rejected and scrapped.
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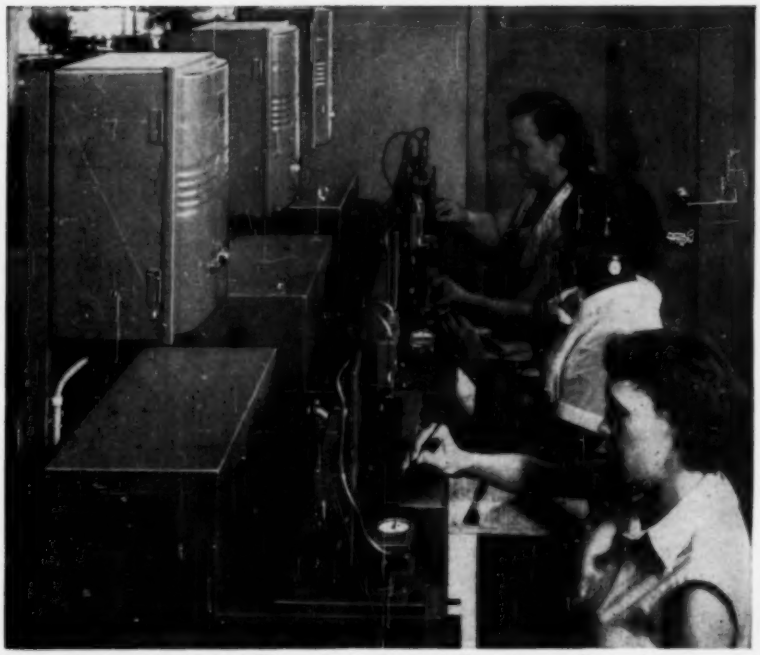

Inspection Costs Drop! These three Federal Electricator Gages inspect two diameters, a shoulder distance and overall length of tiny watch parts . . . simultaneously. Signal lights tell when dimensions are off-size. Dial indicators show how much.

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3. **Material costs** cut through purchase of smaller-sized stock, made possible by holding work to closer tolerances.
4. **Inspection time** halved when visual indicating gages replace ordinary micrometers, vernier calipers and fixed gages. Even higher savings result when Federal multi-dimensional and sorting gages are used.
5. **Quality control** simplified by gages that warn machine operators before they produce scrap.
6. **Assembly speeded** when visual indicating or automatic sorting catches out-of-tolerance parts formerly overlooked because of human error.
7. **Gaging costs** cut when modified Federal stock gages eliminate need for costly special gage engineering.

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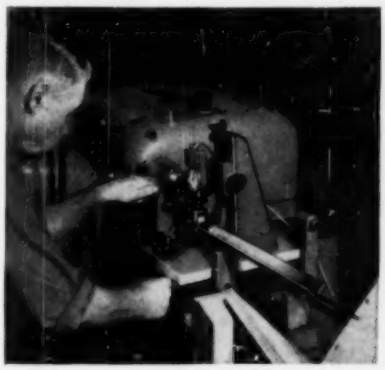
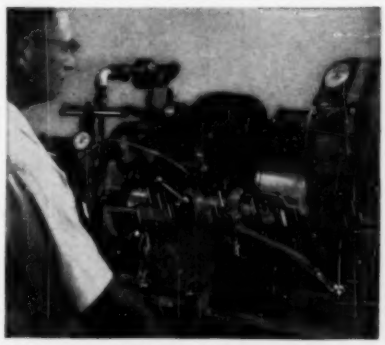
FOR ANYTHING IN MODERN GAGES . . .

DIAL INDICATING, AIR, ELECTRIC, OR ELECTRONIC—FOR INSPECTING, MEASURING, SORTING, OR MACHINE SIZE CONTROL.

Accurate Assembly! Here's how a Federal Dial Indicator is used in balancing and adjusting gears at assembly of an automatic pilot.



Full Length Inspection! This Federal Continuous Measuring Gage checks full length diameter of hard rubber tubes as they emerge from centerless grinder. Signal lights show operator when tube diameters are within, over, or under tolerances. This gage can be modified for COMPLETELY AUTOMATIC SORTING.



Accuracy and Output Increased! Here, the new Federal Arnoldair unit is applied to the well known Arnold continuous grinding gage. This makes faster and more positive dial reading. Work is ground to required dimensions more positively, with less human attention.